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Creek Drainage
Preliminary
Assessment Project

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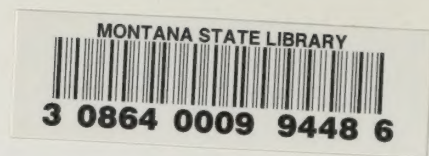
Hughesville/Barker Mining District
Galena Creek Drainage
Preliminary Assessment
Project Report

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HUGHESVILLE/BARKER MINING DISTRICT GALENA CREEK DRAINAGE PRELIMINARY ASSESSMENT PROJECT REPORT

Prepared for:

**Montana Department of State Lands
Abandoned Mines Reclamation Bureau
Capitol Station
Helena, Montana**

Prepared by:

**Chen-Northern, Inc.
Helena, Montana**

February, 1991

EXECUTIVE SUMMARY

Chen-Northern, Inc. (Chen-Northern) completed a preliminary (PA) assessment of the Hughesville/Barker Mining District of north-central Montana. The mining district is located approximately 10 miles east of Monarch, Montana in the Little Belt Mountains.

Large quantities of silver and lead were extracted from the Hughesville/Barker Mining District from the late 1800's until the mid 1940's. As a result of historical mining activity in the area, numerous abandoned mine sites and an abandoned mill site now occupy the district. Mine waste rock dumps and mill tailings waste disposal ponds associated with these historic features are sources of environmental degradation. In addition, acid mine drainage from the underground workings in the district also impact the environment.

The largest mine in the Hughesville/Barker Mining District is the Block P Mine. This mine was initially developed in 1879 and operated intermittently into the 1950's. A 400-ton selective flotation plant was constructed approximately two miles south of the Block P Mine near the mouth of Galena Creek in 1927. An aerial tramway carried ore from the mine to the mill. Mill tailings were contained in two ponds south of the facility. These tailing deposits are visible today as a 15-acre, unvegetated area adjacent to Galena Creek.

The primary metals of concern in the study area are arsenic, cadmium, lead, zinc, copper, iron, and manganese. Metals in the mine waste dumps and mill tailings and acid mine drainage in the study area generally move unchecked into Galena Creek, the primary surface water course in the area. As a result, Galena Creek is impacted by metals to the extent that no fishery is present in the stream and the aquatic community has been severely stressed. Galena Creek flows into the Dry Fork of Belt Creek resulting in identifiable impacts to the quality of water in the Dry Fork of Belt Creek below its confluence with Galena Creek.

Project Objectives

Our general objectives in completing a PA at the Hughesville/Barker Mining District included the following:

- ◆ Collect and collate baseline information to plan and conduct more comprehensive site investigations and evaluations of reclamation alternatives which fully address the requirements of the NCP, NEPA, and MEPA.
- ◆ Provide preliminary identification of operable units within the study area.
- ◆ Provide a rational basis to prioritize subsequent reclamation activities within the study area.

Study Components and Results

Chen-Northern scientists completed several work tasks to achieve project objectives. The primary components of the preliminary assessment included the following:

- ♦ Collation of all available existing environmental data and information pertaining to the site.
- ♦ Surface water investigation.
- ♦ Groundwater investigation.
- ♦ Soils and mine waste investigation.

Data resulting from the field investigations completed during this preliminary assessment and existing information were evaluated in view of project objectives. A brief summary of the results of these various study elements is presented below.

Existing Information

The majority of existing environmental information for the Hughesville/Barker Mining District was collected by the Montana Department of Natural Resources and Conservation (DNRC). DNRC completed an extensive surface water sampling effort during 1973-1977 in the Galena Creek and Dry Fork of Belt Creek drainages. These studies were completed to support an evaluation of reclamation alternatives for the Galena Creek drainage.

Through their analyses, DNRC identified the Block P Mine and associated mine waste dump as the major contributor to metals contamination in Galena Creek. DNRC evaluated several reclamation alternatives for the Block P Mine area and selected a preferred alternative for the site. The selected alternative involved reshaping the top of the Block P Mine dump to minimize precipitation infiltration through the material and isolating Galena Creek from the mine dump. The alternative was implemented in 1977. Subsequent monitoring results indicated that no improvement in site conditions resulted from implementation of the reclamation alternative.

Surface Water Investigation

The surface water investigation completed during the PA included synoptic flow measurements on Galena Creek and collection of samples from selected sites. Field data collection was completed during October, 1990 when low flow conditions were occurring in Galena Creek.

Data resulting from the surface water investigation indicate the following:

- ◆ Galena Creek water quality is measurably impacted by acid mine discharge from the Block P Mine and mine waste dump area. Metal concentrations in the stream increase by an order-of-magnitude from above to below this area.
- ◆ Both chronic and acute ambient water quality criteria in Galena Creek are exceeded for several metals in the reach of stream below the Block P Mine area. Maximum contaminant levels for cadmium are also exceeded.
- ◆ Metals concentrations in Galena Creek generally decrease and change form in the lower reaches of the stream due to the natural attenuating mechanisms associated with limestone bedrock which subcrops to the stream in this area. However, Galena Creek at its mouth still exceeded ambient water quality criteria for several metals.
- ◆ Galena Creek, during low flow conditions, generally gains flow along its course. This phenomenon presumably results from groundwater inflow to the stream. Some data collected during the PA indicate the stream loses flow in its lower reaches near the Block P Mill tailing impoundments.
- ◆ The impact of the input of Galena Creek to the Dry Fork of Belt Creek is measurable in the receiving stream. The Dry Fork below its confluence with Galena Creek exceeded ambient water quality criteria for certain metals. Natural attenuating mechanisms occurring in the Dry Fork of Belt Creek appear to minimize the extent of metals contamination in the stream.

Groundwater Investigation

Seven monitoring wells were installed at sites throughout the study area to gain a general understanding of the relationship between the area's groundwater and surface water systems. All wells installed were sampled and slug tests performed. Elevations of static water levels were compared to stream stage to determine the influent/effluent characteristics of Galena Creek.

Results of the groundwater investigation indicated the following:

- ◆ Groundwater in two general areas within the study area contain relatively high concentrations of metals. These include the Block P Mine area and the area below the Block P Mill tailings.

- ◆ Hydraulic conductivities in Galena Creek alluvium are generally higher than in adjacent and subjacent bedrock units. Bedrock, where fractured, exhibited measurably higher hydraulic conductivities than massive units.
- ◆ Groundwater data generally supported locations of influent and effluent reaches of Galena Creek determined during the surface water investigation.
- ◆ The underground mine workings in the vicinity of the Block P Mine appear to exert a significant influence on groundwater flow paths in that portion of the study area. It is probable that other underground mines in the area also influence groundwater movement and quality.

Soils and Mine Waste Investigation

Four types of soils and mine waste material were identified in the Hughesville/Barker Mining District during the PA. These included native soil, waste rock dumps, mill tailings, and streamside tailings. Each type of material was mapped and sampled during this investigation. Results of this study included the following:

- ◆ Metals concentrations in all material types sampled during the PA were above published background concentrations in soils.
- ◆ All mine and mill wastes in the study area are very acidic and have high acid producing capacities. This relationship along with high metal concentrations inhibit vegetative growth on all mine and mill waste materials. Nearly all waste material disposal areas are currently devoid of vegetation.
- ◆ Saturated paste water extract metal concentrations are relatively high in all materials sampled. The Block P Mill tailings material have the highest water extract metal concentrations of all waste materials and are one to two orders of magnitude higher than extracts from mine waste or streamside tailings samples. The relatively high concentrations of metals measured in water extracts are indicative of the relative solubility of the metals and the potential for entrainment of these metals into the environment.
- ◆ Streamside tailings and waste rock materials have similar concentrations of total and water extract metals. Extract metal concentrations in streamside tailings are relatively low (compared to mill tailings), indicating considerable leaching of metals has probably occurred post-deposition.
- ◆ Sulfur fractionation indicates the predominant form of sulfur in all waste materials occurs as soluble sulfate sulfur and pyritic sulfur. A smaller proportion occurs as jarosite sulfur.

Site Problems

Several environmental problems in the Galena Creek drainage were identified during this PA. These include:

- ◆ Metals-laden groundwater enters Galena Creek, particularly in the vicinity of the Block P Mine and dump. This input deleteriously impacts Galena Creek water quality. The source of this groundwater input appears to be associated with the underground mine workings of the Block P Mine.
- ◆ Metals-laden groundwater is present below the Block P tailings impoundments. This water moves to the south and either directly enters Dry Fork of Belt Creek and Galena Creek or enters the Dry Fork at some point below the confluence of the two streams.
- ◆ Many area mine waste rock dumps are positioned adjacent to and above Galena Creek. Precipitation and snowmelt runoff erodes these materials and transports metals-laden sediment into Galena Creek. Such occurrences deleteriously impact the quality of water in Galena Creek and the Dry Fork of Belt Creek. Increased sedimentation rates also probably occur during runoff events. The Block P Mine waste dump is the largest dump in the area and is located directly adjacent to Galena Creek. Its proximity to the stream makes this waste dump the most problematic dump with respect to erosional impacts on the stream.
- ◆ Portions of the Block P tailings impoundments are located within the floodplain of Galena Creek. Materials contained in these impoundments contain relatively high concentrations of metals which are readily solubilized in water. The impoundments are subject to erosion or possibly catastrophic failure in the event of a large flood. Ramifications of such an occurrence would likely result in the release of several tens of thousands of cubic yards of tailings into Galena Creek and the Dry Fork of Belt Creek.
- ◆ Streamside tailings are present along reaches of Galena Creek and the Dry Fork of Belt Creek. These deposits are located along the active floodplain of these streams and are subject to erosion and entrainment during moderately high flow events in the drainage basins. The tailings contain metals which are subject to solubilization by surface flow and which can be transported in suspension. These deposits probably impact the quality of water in Galena Creek and the Dry Fork of Belt Creek during out-of-bank flow events.
- ◆ Acid mine drainage emanating from abandoned underground mines in the area either directly or indirectly enters Galena Creek. The most prominent

area in which AMD occurs is in the vicinity of the Liberty and Danny T Mines. The impact of AMD from these sources on quality of water in Galena Creek is probably minimal with respect to other inputs to the stream but is suspected to be greatest during low flow and baseflow conditions. Data collected during this PA indicate that AMD from the Moulton Mine in the upper reaches of Galena Creek causes increased metals levels in the receiving stream.

These problems collectively impact the primary receiving stream in the study area, Galena Creek, and the Dry Fork of Belt Creek below its confluence with Galena Creek. The impacts to the surface water courses are primarily elevated metals concentrations with respect to ambient water quality criteria and an artificially high rate of sedimentation.

Operable Units

Based on the results from this PA, several operable units have been identified within the study area. An operable unit is defined as a discrete action that comprises an incremental step toward comprehensively addressing site problems. The cleanup of a site can be divided into a number of operable units, depending on the complexity of the problems associated with the site. Operable units may address geographical portions of a site, specific site problems, or initial phases of an action, or may consist of any set of actions performed over time or any actions that are concurrent but located in different parts of a site.

Based on information collected during this PA, contaminant sources identified in the Hughesville/Barker Mining District are best divided into operable units based on geography and problem types. We recommend dividing the study area into the following operable units:

- ◆ The Block P Mill Tailing Impoundments -- This operable unit would include the upper and lower tailing ponds, a buffer area on the east, north, and south sides of the deposits, and an area south of the impoundments to the confluence of Galena Creek and the Dry Fork of Belt Creek. This area represents an operable unit because the lower impoundment at the site is situated in the floodplain of Galena Creek and is subject to catastrophic failure during flood events. In addition, the groundwater contamination identified south of the impoundments is derived from the tailings ponds.
- ◆ The Block P Mine and Mine Waste Dump -- This operable unit would include the large mine waste dump at the site and the underground mine workings associated with the Block P and Wright-Edwards Mines. This area appears to exert the greatest impacts to surface water quality in the drainage during low flow and baseflow conditions. Large loads of metals enter Galena Creek in this area via groundwater inflow from the mine

workings. Galena Creek also erodes the toe of the mine waste dump during relatively high stage conditions in the stream. Runoff erodes the mine waste dump and directly enters Galena Creek.

- ◆ Streamside Tailings -- These deposits represent a separate operable unit because concentrations of water extractable metals in the material is similar and the location of the deposits with respect to Galena Creek is comparable. Streamside tailings are visible along various reaches of Galena Creek and the reach of the Dry Fork of Belt Creek below its confluence with Galena Creek. These deposits are subject to erosion and entrainment by Galena Creek during high flow events. The deposits represent an acute source of metals input to Galena Creek.
- ◆ Various Mine Waste Dumps and Associated AMD -- This operable unit would include all historical mines and associated mine waste dumps in the drainage area exclusive of the Block P Mine operable unit. Mines in this operable unit would include, but not be limited to the following:
 - Liberty
 - Danny T
 - Marceline
 - Wright/Edwards
 - Queen of the Hills
 - Tiger
 - Moulton
 - Silver Bell
 - St. Louis
 - Defiance
 - Dr. Kollach
 - May & Edna
 - Paragon
 - Carter
 - Harrison

In addition to hazardous mine openings, problems at mines included in this operable unit are associated with either acid mine drainage and/or erosion and entrainment of mine waste material. Because all these mines and mine waste dumps are located in the Galena Creek drainage and because the degree of impact to the quality of Galena Creek from any one site is unknown, it is logical to group these areas into one operable unit. If further evaluation of this operable unit is contemplated, it may be prudent to further prioritize reclamation activities at the mine sites within this operable unit.

Information collected during this PA suggest that, of these mines, the Wright/Edwards, Danny T, and Marceline Mines may exert the greatest impact to Galena Creek water quality. Further evaluation of the relative contribution from these various mine sites will be necessary to provide a better basis to prioritize reclamation efforts within this operable unit.

Prioritization of the foregoing operable units with respect to the sequencing of reclamation should be based on reclamation objectives established by the AMRB. If AMRB's objective

is to eliminate or minimize environmental degradation caused by the various contaminant sources in the Galena Creek drainage, it follows that the sequence in which operable units are reclaimed should be:

- (1) Block P Mill Tailings Operable Unit.
- (2) Block P Mine and Waste Dump Operable Unit
- (3) Streamside Tailings Operable Unit.
- (4) Abandoned Mine and Waste Dump Operable Unit.

The rationale for sequencing the operable units in this order is in the degree of environmental impact associated with each operable unit or the potential for impact to the environment by an operable unit. The Block P mill tailings ranks highest on the priority list because of the potential for catastrophic failure of the lower impoundment and the subsequent release of large quantities of metals-laden sediments. Such an occurrence would obviously impact a large portion of the Dry Fork of Belt Creek and possibly Belt Creek. In the event of such a catastrophe, other environmental problems in the Galena Creek drainage would become relatively insignificant.

The Block P Mine and associated waste dump is ranked second on the priority list because of the chronic impact this area exerts on water quality in Galena Creek and the Dry Fork of Belt Creek. During most flow conditions in the streams, the majority of metals loads are derived from this source.

The streamside tailings operable unit and the abandoned mines operable unit may rank equally on the priority list for reclamation. This is because the relative impact on the environment from each operable unit is unknown, given the current understanding of the Galena Creek drainage. The impact from each operable unit may become more discernible if and when the two top ranking operable units are reclaimed. A decision resolving which of these two operable units has a higher priority may best be accommodated by delaying the decision until determinations of the relative significance of environmental impacts from these operable units are made.

If the AMRB elects to formulate other objectives for reclamation of the Galena Creek drainage, the order in which operable units in the area are carried forward in the AMRB hard rock reclamation process may be modified.

TABLE OF CONTENTS

	<u>Page</u>
EXECUTIVE SUMMARY	ES-1
LIST OF FIGURES	iv
LIST OF TABLES	viii
LIST OF APPENDICES	x
1.0 INTRODUCTION	1-1
1.1 PROJECT BACKGROUND	1-1
1.2 SITE DESCRIPTION	1-3
1.3 GENERAL SITE HISTORY	1-6
1.4 SITE CHARACTERISTICS	1-8
1.4.1 <u>Physiography/Climatology</u>	1-8
1.4.2 <u>Geology</u>	1-9
1.4.3 <u>Soils</u>	1-10
1.4.4 <u>Surface Water</u>	1-10
1.4.5 <u>Groundwater</u>	1-12
1.5 PROJECT OBJECTIVES	1-12
2.0 SUMMARY OF EXISTING INFORMATION/DATA	2-1
2.1 SURFACE WATER DATA	2-1
2.1.1 <u>DNRC Data</u>	2-1
2.1.2 <u>DSL Data</u>	2-5
2.2 PREVIOUS RECLAMATION EVALUATIONS	2-6
2.2.1 <u>DNRC Studies</u>	2-6
2.2.2 <u>DSL Studies</u>	2-3
2.3 DEMOGRAPHIC DATA	2-8
2.4 LAND USE	2-8
2.5 LAND OWNERSHIP	2-11
2.6 EXTENT OF MINE WASTES	2-12
2.7 ADIT AND SHAFT LOCATIONS	2-18
2.8 DOMESTIC WELL AND SPRING INVENTORY	2-18
2.9 MINERAL OWNERSHIP	2-18
3.0 SURFACE WATER INVESTIGATION	3-1
3.1 METHODS	3-1
3.1.1 <u>Sampling/Flow Measurement Site Selection</u>	3-1
3.1.2 <u>Streamflow Gaging</u>	3-4
3.1.3 <u>Sampling</u>	3-4
3.2 CHANGES TO THE PROJECT SAMPLING AND ANALYSIS PLAN	3-8

TABLE OF CONTENTS (continued)

	<u>Page</u>
3.3 PRESENTATION OF DATA AND RESULTS	3-9
3.3.1 <u>Flow Data</u>	3-9
3.3.1.1 Preliminary Assessment Data	3-9
3.3.1.2 DNRC Data	3-12
3.3.2 <u>Water Quality Data</u>	3-12
3.3.2.1 Common Ions	3-18
3.3.2.2 Specific Conductance and pH	3-21
3.3.2.3 Metals	3-23
3.3.2.4 Other Parameters	3-48
3.3.2.5 Water Quality Criteria Exceedances	3-48
4.0 GROUNDWATER INVESTIGATION	4-1
4.1 METHODS	4-1
4.1.1 <u>Monitoring Well Siting</u>	4-1
4.1.2 <u>Monitoring Well Installation</u>	4-2
4.1.3 <u>Groundwater Sampling</u>	4-6
4.1.4 <u>Water Level Measurement</u>	4-8
4.1.5 <u>Survey</u>	4-8
4.1.6 <u>Aquifer Testing</u>	4-8
4.2 CHANGES TO THE PROJECT SAMPLING AND ANALYSIS PLAN	4-9
4.3 PRESENTATION AND INTERPRETATION OF DATA	4-9
4.3.1 <u>Monitoring Well Installation</u>	4-9
4.3.1.1 Lithology	4-9
4.3.1.2 Monitoring Well Completion	4-11
4.3.2 <u>Groundwater Quality</u>	4-11
4.3.2.1 Common Ions	4-11
4.3.2.2 Metals and pH	4-14
4.3.3 <u>Groundwater Occurrence</u>	4-19
4.3.4 <u>Groundwater Movement</u>	4-21
4.3.5 <u>Aquifer Testing</u>	4-23

TABLE OF CONTENTS (continued)

	<u>Page</u>
5.0 SOILS/MINE WASTE INVESTIGATION	5-1
5.1 METHODS	5-1
5.1.1 <u>Soil/Mine Waste Sample Site Selection</u>	5-1
5.1.2 <u>Soil/Mine Waste Sampling</u>	5-8
5.1.3 <u>Sample Selection Process For Laboratory Analysis</u>	5-9
5.1.4 <u>XRF Analysis</u>	5-11
5.2 CHANGES TO THE SAMPLING AND ANALYSIS PLAN	5-12
5.3 PRESENTATION OF DATA AND RESULTS	5-13
5.3.1 <u>Waste Rock</u>	5-13
5.3.2 <u>Mill Waste</u>	5-21
5.3.3 <u>Streamside Tailings</u>	5-27
5.3.4 <u>Native Soil</u>	5-31
6.0 DATA VALIDATION	6-1
6.1 ACCURACY	6-1
6.1.1 <u>Surface Water Accuracy</u>	6-2
6.1.2 <u>Groundwater Accuracy</u>	6-6
6.1.3 <u>Soil Accuracy</u>	6-6
6.2 PRECISION	6-6
6.2.1 <u>Field Precision</u>	6-10
6.2.2 <u>Laboratory Precision</u>	6-11
6.3 REPRESENTATIVENESS	6-11
6.3.1 <u>Surface Water Representativeness Statement</u>	6-13
6.4 COMPLETENESS	6-13
6.5 COMPARABILITY	6-17
6.5.1 <u>Surface Water Comparability Statement</u>	6-17
7.0 CONCLUSIONS	7-1
7.1 CONCEPTUAL MODEL OF SITE PROCESSES	7-1
7.1.1 <u>Contaminants of Concern</u>	7-1
7.1.2 <u>Contaminant Sources</u>	7-1
7.1.3 <u>Pathways of Contaminant Movement</u>	7-3
7.1.4 <u>Receptors</u>	7-5
7.1.5 <u>Site Problems</u>	7-6
7.2 OPERABLE UNITS	7-7
8.0 REFERENCES CITED	8-1

LIST OF FIGURES

	<u>Page</u>
1-1 Location and Vicinity Map; Hughesville/Barker Mining District, Montana . .	1-2
1-2 Project Flow Diagram; AMRB Hardrock Reclamation Projects	1-4
1-3 Site Map, Preliminary Assessment; Hughesville/Barker Mining District, Montana	1-5
2-1 Surface Water Sampling Sites Used by the DNRC (1973-1977)	2-2
2-2 Residences, Domestic Wells, and Springs in Hughesville/Barker Mining District	2-9
2-3 Adits, Shafts, and Mine and Mill Waste Deposits in Hughesville/Barker Mining District	2-13
2-4 Patented Claims and Public Lands in the Hughesville/Barker Mining District	2-19
3-1 Surface Water Gaging and Sampling Stations; Galena Creek Preliminary Assessment	3-2
3-2 Spatial Distribution of Discharge in Galena Creek; October, 1990; Galena Creek Preliminary Assessment	3-11
3-3 Hydrographs of Flow at Station DF-7 on Galena Creek (1973-1978)	3-13
3-4 Hydrographs of Flow at Station DF-1 on Galena Creek (1973-1978)	3-14
3-5 Hydrographs of Flow at the Block P Adit Discharge (Station DF-6) from 1974-1977	3-15
3-6 Hydrographs of Flow at Station DF-2 on Silver Creek (1974-1978)	3-16
3-7 Hydrographs of Flow at from the Liberty Mine Adit (Station DF-3) from 1974-1977	3-17
3-8 Trilinear Diagram of Major Ions in Surface Water; Galena Creek Preliminary Assessment	3-19
3-9 Spatial Plot of Stiff Diagrams of Major Ions in Surface Water; Galena Creek Preliminary Assessment	3-20

LIST OF FIGURES (continued)

	<u>Page</u>
3-10 Discharge, Specific Conductance, and pH Values in Galena Creek; Galena Creek Preliminary Assessment	3-22
3-11 Summary of Metals Concentrations in Galena Creek; Galena Creek Preliminary Assessment	3-24
3-12 Cadmium Concentrations in Galena Creek; October, 1990	3-25
3-13 Copper Concentrations in Galena Creek; October, 1990	3-26
3-14 Zinc Concentrations in Galena Creek; October, 1990	3-27
3-15 Iron Concentrations in Galena Creek; October, 1990	3-28
3-16 Lead Concentrations in Galena Creek; October, 1990	3-29
3-17 Manganese Concentrations in Galena Creek; October, 1990	3-30
3-18 Summary of Metals Concentrations in Point Sources to Galena Creek; Galena Creek Preliminary Assessment	3-31
3-19 Copper Loads in Galena Creek; October, 1990	3-33
3-20 Zinc Loads in Galena Creek; October, 1990	3-34
3-21 Iron Loads in Galena Creek; October, 1990	3-35
3-22 Lead Loads in Galena Creek; October, 1990	3-36
3-23 Manganese Loads in Galena Creek; October, 1990	3-37
3-24 Selected Metals Loads from Point Sources; October, 1990	3-39
3-25 Total Recoverable Iron Concentrations and Flow Data; Upper Weir on Galena Creek	3-40
3-26 Total Recoverable Copper Concentrations and Flow Data; Upper Weir on Galena Creek	3-41

LIST OF FIGURES (continued)

	<u>Page</u>
3-27 Plots of Selected Metals Concentrations, Specific Conductivity, and Flow versus Time in Discharge from the Block P Mine Adit in 1973	3-43
3-28 Total Recoverable Iron and Flow at Station DF-4 (1973-1977)	3-44
3-29 Comparison of Iron Concentrations in Galena Creek; 1976-1990	3-45
3-30 Total Recoverable Copper Concentrations and Flow Data; Lower Weir on Galena Creek	3-46
3-31 Total Recoverable Zinc Concentrations and Flow Data; Lower Weir on Galena Creek	3-47
3-32 Comparison of Arsenic Concentrations in Galena Creek and Water Quality Criteria; October, 1990; Galena Creek Preliminary Assessment	3-49
3-33 Comparison of Cadmium Concentrations in Galena Creek and Water Quality Criteria; October, 1990; Galena Creek Preliminary Assessment	3-50
3-34 Comparison of Copper Concentrations in Galena Creek and Water Quality Criteria; October, 1990; Galena Creek Preliminary Assessment	3-51
3-35 Comparison of Lead Concentrations in Galena Creek and Water Quality Criteria; October, 1990; Galena Creek Preliminary Assessment	3-52
3-36 Comparison of Zinc Concentrations in Galena Creek and Water Quality Criteria; October, 1990; Galena Creek Preliminary Assessment	3-53
4-1 Monitoring Well Locations; Galena Creek Preliminary Assessment	4-3
4-2 Schematic of Typical Monitoring Well Design; Galena Creek Preliminary Assessment	4-5
4-3 Trilinear Diagram of Major Ions in Groundwater; Galena Creek Preliminary Assessment	4-12
4-4 Spatial Plot of Stiff Diagrams of Major Ions in Groundwater; Galena Creek Preliminary Assessment	4-13

LIST OF FIGURES (continued)

	<u>Page</u>
4-5 Summary of Metals Concentrations and pH in Groundwater; Galena Creek Preliminary Assessment	4-15
4-6 Concentrations of Cadmium, Iron, Lead, and Zinc in Groundwater and Adjacent Surface Water Sampling Stations; Galena Creek Preliminary Assessment	4-18
5-1 Soils/Mine Waste Sample Sites; Galena Creek Preliminary Assessment	5-3
5-2 Total Metal Concentrations by Depth Interval in Waste Rock Material	5-19
5-3 Total Metal Concentrations by Depth Interval in Mill Tailings	5-26
5-4 Total Metal Concentrations by Depth Interval in Streamside Tailings	5-30
7-1 Conceptual Model of Processes and Environmental Problems in the Hughesville/Barker Mining District	7-2

LIST OF TABLES

	<u>Page</u>
2-1 Summary of Parameters Analyzed by the DNRC During Monthly Sampling Episodes (1973-1977)	2-4
2-2 Private Landowners and Acreage Owned in the Hughesville/Barker Mining District	2-11
2-3 Mineral Ownership in the Hughesville/Barker Mining District	2-21
3-1 Descriptions of Surface Water Sampling Sites; Galena Creek Preliminary Assessment	3-5
3-2 Surface Water Parameter List; Galena Creek Preliminary Assessment	3-7
4-1 Groundwater Parameter List; Galena Creek Preliminary Assessment	4-7
4-2 Summary of Groundwater Level Measurements and Survey Data; Galena Creek Preliminary Assessment	4-22
4-3 Summary of Slug Test Data; Galena Creek Preliminary Assessment	4-24
5-1 Soil/Mine Waste Sample Areas and Sample Quantities; Galena Creek Preliminary Assessment	5-2
5-2 Soil/Mine Waste Analytical Methods and Required Detection Limits; Galena Creek Preliminary Assessment	5-10
5-3 Average Waste Rock Physical Characteristics; Galena Creek Preliminary Assessment	5-14
5-4 Average Concentrations of Total and Extractable Metals in Waste Rock; Galena Creek Preliminary Assessment	5-15
5-5 Significant Differences in Physicochemical Properties Between Surface and Near-surface Waste Rock Samples; Galena Creek Preliminary Assessment	5-18
5-6 Summary Statistics for Metal Concentrations in Waste Rock Material by XRF and Laboratory Analysis; Galena Creek Preliminary Assessment	5-20

LIST OF TABLES (continued)

	<u>Page</u>
5-7 Comparison of Total Metal Group Means Based on Waste Rock Dump Locations; Galena Creek Preliminary Assessment	5-20
5-8 Average Mill Tailings Physical Characteristics; Galena Creek Preliminary Assessment	5-23
5-9 Average Concentrations of Total and Extractable Metals in Mill Tailings; Galena Creek Preliminary Assessment	5-24
5-10 Summary Statistics for Total Metal Concentrations in Mill Tailings by XRF and Laboratory Analysis; Galena Creek Preliminary Assessment	5-26
5-11 Average Streamside Tailings Physical Characteristics; Galena Creek Preliminary Assessment	5-28
5-12 Average Concentrations of Total and Extractable Metals in Streamside Tailings; Galena Creek Preliminary Assessment	5-29
5-13 Summary Statistics for Total Metal Concentrations in Streamside Tailings by XRF and Laboratory Analysis; Galena Creek Preliminary Assessment	5-31
6-1 Surface Water Accuracy Statement	6-3
6-2 Groundwater Accuracy Statement	6-4
6-3	6-5
6-4 Surface Water Precision Statement	6-7
6-5 Groundwater Precision Statement	6-8
6-6	6-9
6-7 Surface Water Completeness Summary, Galena Creek Preliminary Assessment, October, 1990	6-14
6-8 Groundwater Completeness Summary, Galena Creek Preliminary Assessment; October, 1990	6-15

LIST OF TABLES (continued)

	<u>Page</u>
6-9 Soil Completeness Summary, Galena Creek Preliminary Assessment; October, 1990	6-16
6-10 Comparison of Surface Water Parameter Lists and Detection Limits For Galena Creek Preliminary Assessment and MDNRC Surface Water Data	6-18

LIST OF APPENDICES

A	Surface Water Quality Data Base
B	Groundwater
B-1	Monitoring Well Lithologic and Completion Logs
B-2	Groundwater Quality Data Base
B-3	Slug Test Data and Analyses
C	Soils/Mine Waste
C-1	XRF Data Base, Regression Analyses, and Predictive Curves for XRF Data
C-2	Soils/Mine Waste Laboratory, Gradation, And Hydrometer Data Base

1.0 INTRODUCTION

Chen-Northern Inc. (Chen-Northern) personnel prepared this report for the Montana Department of State Lands (MDSL) Abandoned Mine Reclamation Bureau (AMRB) to fulfill requirements of Task Order J of Chen-Northern's contract with MDSL dated June 25, 1990. We have presented in this report descriptions of activities completed in conjunction with a preliminary assessment (PA) of the Galena Creek drainage in the Hughesville/Barker Mining District. We also have included results of the PA and have provided recommendations identifying and prioritizing operable units within the study area.

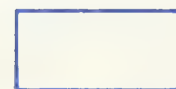
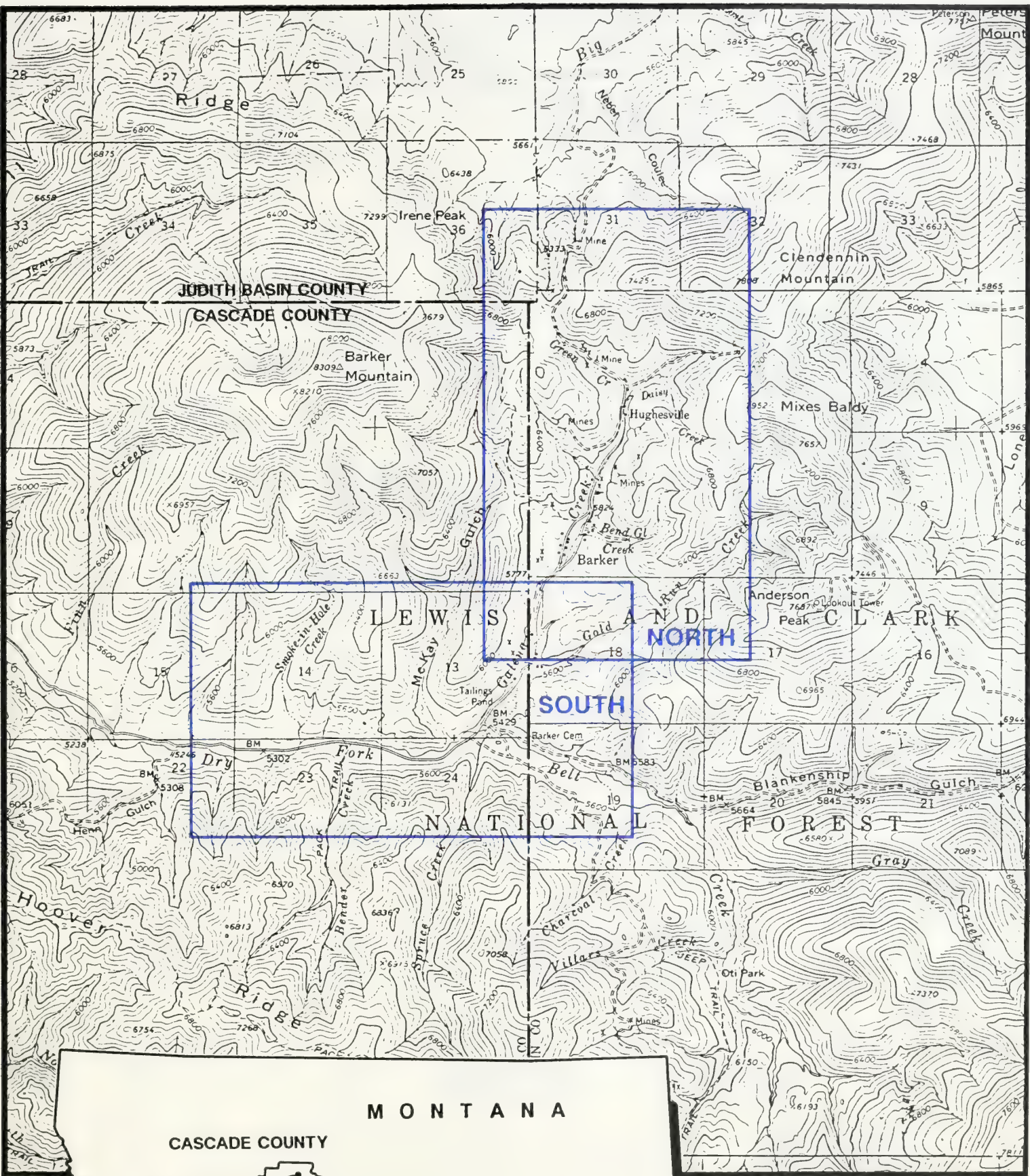
Chen-Northern scientists completed field work during this PA in accordance with a project work plan (Chen-Northern, 1990a), a sampling and analysis plan (Chen-Northern, 1990b), and a health and safety plan (Chen-Northern, 1990c). We also developed a community relations plan (Chen-Northern, 1990d) to provide a means for apprising the public of the project activities. The AMRB is implementing the community relations program for this project.

The Hughesville/Barker Mining District is located approximately 12 miles east of the town of Monarch in the Little Belt Mountains of north central Montana (Figure 1-1). The site has a relatively long history of environmental degradation due to previous mining and milling activity in the area. The AMRB considers determining the feasibility of reclamation of the district as a high priority in their program.

1.1 PROJECT BACKGROUND

The AMR program in Montana has recently shifted focus from abandoned coal mine reclamation to abandoned hardrock mine reclamation. This change occurred because all abandoned coal mine reclamation work in the state has been certified as complete.

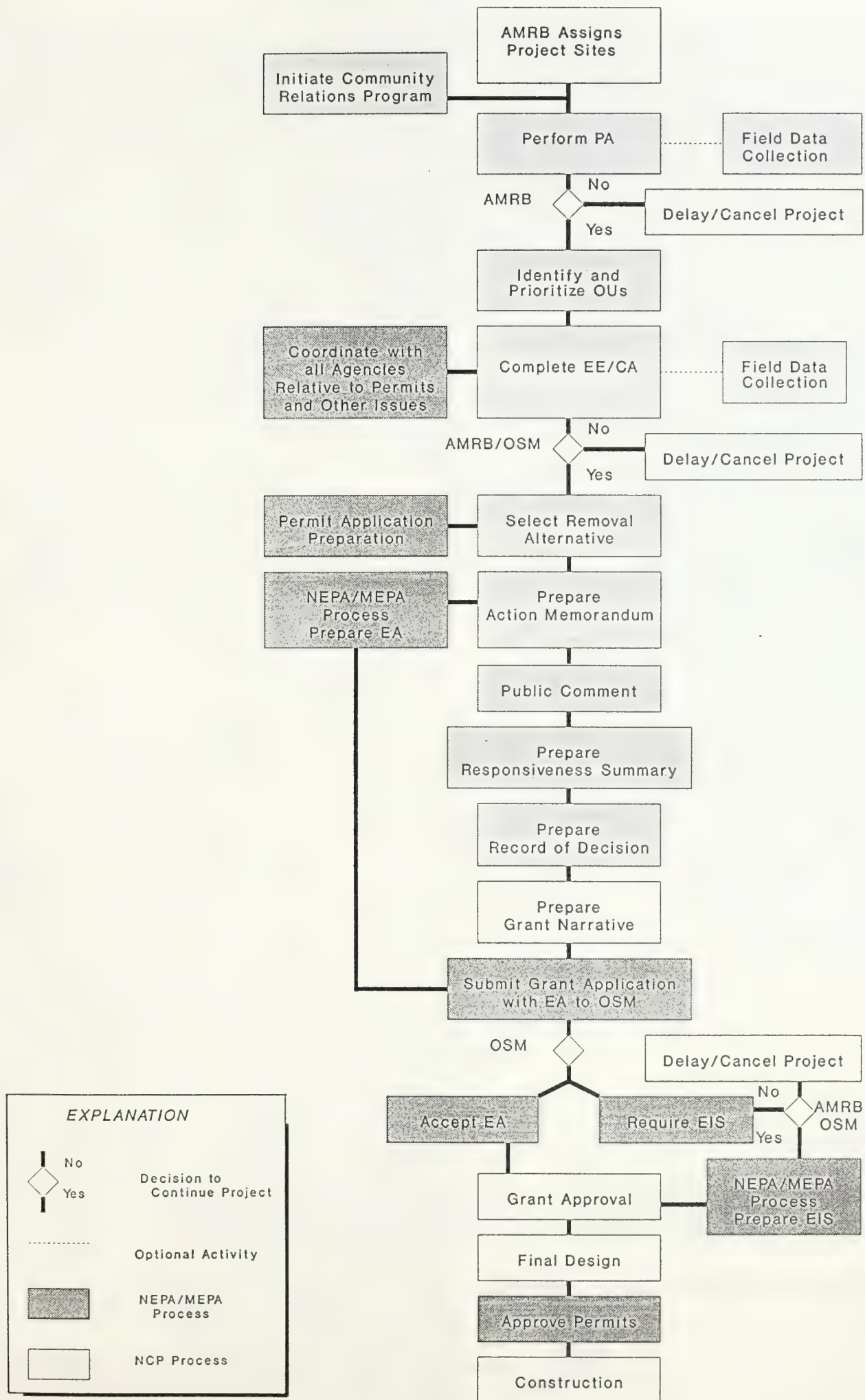
With the changeover to hardrock mine reclamation, the AMRB is instituting changes in its approach to reclamation projects to be consistent with procedures described for removal actions under the National Contingency Plan (NCP, §§ 300.410, 300.415). The approach



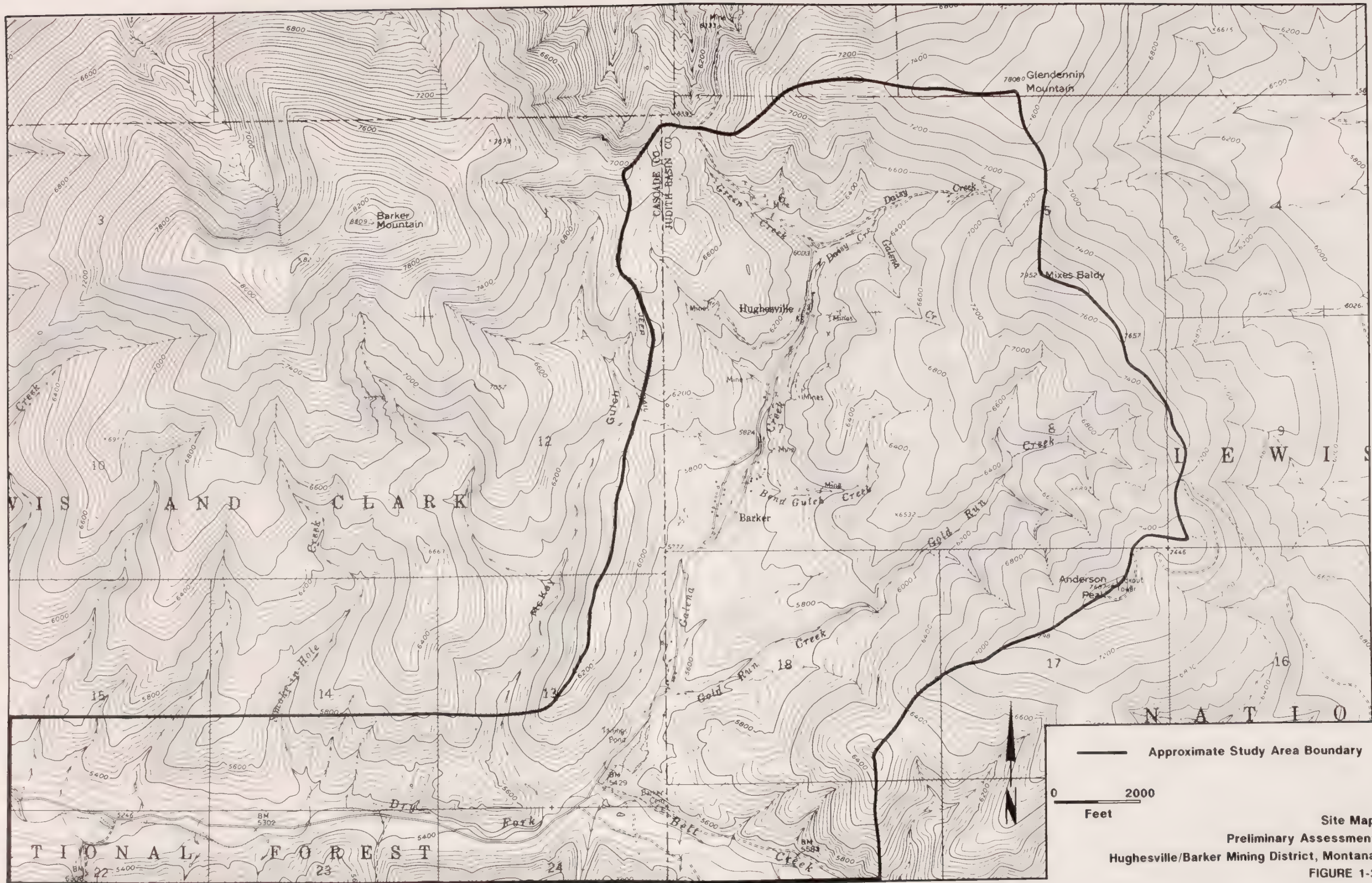
Location of Area Maps

Location and Vicinity Map
Hughesville/Barker Mining District, Montana

FIGURE 1-1



Project Flow Diagram
AMRB Hardrock Reclamation Projects
FIGURE 1-2



— Approximate Study Area Boundary

0 2000
Feet



Site Map
Preliminary Assessment
Hughesville/Barker Mining District, Montana
FIGURE 1-3

used by the AMRB also fulfills all requirements of the Montana Environmental Policy Act (MEPA) and the National Environmental Policy Act (NEPA). Figure 1-2 shows the process utilized by the AMRB.

The initial step in the process guiding AMRB reclamation activities is project assignment by the AMRB to their contractors. Chen-Northern inventoried the various abandoned hardrock mine sites in Montana in 1987-1989. We developed a computerized data base as a result of this effort to track all information produced during the inventory. The AMRB reviewed the inventory data base and prioritized the various sites with respect to degree of environmental degradation and potential for human health impacts. The AMRB selected project sites determined as high priorities for reclamation for the initial assignments. The AMRB subsequently assigned the Hughesville/Barker Mining District to Chen-Northern for further evaluation.

The second step in the AMRB investigatory process (Figure 1-2) involves completion of a preliminary assessment (PA) of the project site. This report is the result of completion of the PA phase of the project in the Hughesville/Barker Mining District.

The U.S. Forest Service also has an interest in reclaiming areas within the Hughesville/Barker Mining District. Because of this, efforts are being made to coordinate project activities with the U.S. Forest Service.

1.2 SITE DESCRIPTION

The Hughesville/Barker Mining District is located approximately 10 miles east of the town of Monarch, Montana (Figure 1-1). Boundaries of the district are not distinct but historic mines associated with the district are present in both Cascade and Judith Basin Counties. The district is most easily accessed from the west via U.S. Forest Service road number 120 which joins with Montana Highway 89 near Monarch.

The study area identified for this PA includes the entire Galena Creek drainage basin and a portion of the Dry Fork Belt Creek watershed (Figure 1-3). Watershed boundaries were

selected for the study area limits because existing data for the site were insufficient to identify the nature and extent of site contamination. The project work plan (Chen-Northern , 1990a) further describes the rationale used to determine the study area for the Hughesville/Barker Mining District.

1.3 GENERAL SITE HISTORY

Buck Barker and Pat Hughes discovered silver and lead deposits near Barker, Montana (first known as Clendennin) on October 23, 1879 (Robertson, 1951). Other persons soon made discoveries which resulted in a rush to the new camp. The miners located hundreds of claims and feverish mining activity resulted. Several of the mines soon became important producers.

The early miners mined large quantities of high-grade ore from the district and hauled it to Fort Benton by pack train or horse/oxen-drawn wagons. The miners shipped the ore by river steamers to Kansas City, St. Louis, and elsewhere for ocean shipment to Swansea, Wales, for smelting (Robertson, 1951). Early workers constructed smelters at Clendennin and at Hughesville to avoid the high transportation costs. However, most of the high-grade ore and bullion produced during 1883 and 1884 was shipped by river to Omaha, Nebraska. The smelter at Hughesville operated only a short time because the furnace did not have a suitable refractory lining. The 40-ton smelter at Clendennin was equipped with a water jacketed furnace. Colonel George Clendennin operated this smelter for about 18 months and produced \$375,000 worth of bullion (Robertson, 1951).

Mining operations in the Barker district waned during the late 1800's with the depletion of the rich, near-surface, argentiferous, lead-sulfate ore bodies. Deeper exploration in most of the mines developed lower-grade base ore that could not be mined and shipped at a profit.

A railroad was constructed from Monarch to Barker in 1891. Several of the larger mines then resumed operations. The demonetization of silver in 1892, however, forced most of them to close. The spur line from Monarch to Barker was removed in 1902.

After some years of inactivity, the Block P mine was leased to the United Smelting and Refining Company in 1898 (Robertson, 1951). The company operated the mines until about 1902, shipping the ore to its smelter at Great Falls. Ownership of most of the claims by that time had been acquired by T.C. Power, who then organized the Block P Mining Company. The company was named after the flag design of Power's Missouri River steamboats. This company and lessees operated the mine intermittently on a small scale for several years.

A 75-ton gravity mill was built during 1910 and 1911. Mill capacity was increased to 100 tons in 1920. Operations continued more or less steadily until 1927 when the Block P Mining Company holdings were purchased by the St. Joseph Lead Company. The company constructed a modern, 400-ton, selective flotation plant at a site just south of Barker (Robertson, 1951). The railroad spur from Monarch to Barker was also rebuilt. The mine was equipped with a new steel headframe and ore bins and extensive development was completed. A 10,250 foot aerial tramway was constructed between the mine headframe and the new flotation plant. Mining and milling continued steadily until September 30, 1930, when all operations were suspended because of unfavorable market conditions (Robertson, 1951).

Operations resumed in 1941 and continued until October, 1943, when all company operations ceased. The mine and most of its equipment were sold to Thorson Brothers and Brazee. The mill was dismantled, the railroad tracks were removed, and the railroad right-of-way was abandoned.

Thorson Brothers and Brazee sold their holdings about a year later to the American Smelting and Refining Company but reserved the right to mine ore from the adits above the collar of the shaft which they did for some years thereafter. The Block P property was sold to its present owners, Harry J. Anderson and Peter Antonioli (Emerald Resources) in 1973.

The Block P properties were leased to Amax Exploration, Inc. in 1981. Amax was issued a permit by the Montana Department of State Lands to re-establish mining operations in

a portion of the district. Their mining plans called for reprocessing of the mine dumps and old tailings pond for residual ore. To date, none of the tailings material from the mine dumps or mill tailings ponds have been reprocessed. Recent exploration activities have added mine waste to the Block P mine dump and have increased the extent of disturbed areas at several mine sites. Amax recently allowed their lease to the property expire without renewal (McBride, personal communication). There has been no recent exploration activity in the area.

1.4 SITE CHARACTERISTICS

This section of the report describes physical, climatological, geological, hydrological, demographical, and morphological characteristics of the Hughesville/Barker Mining District.

1.4.1 Physiography/Climatology

The Hughesville/Barker Mining District is located in Cascade and Judith Basin Counties, Montana, approximately 40 miles southeast of Great Falls (Figure 1-1). The district is in the northeast portion of the Lewis and Clark National Forest, which encompasses most of the Little Belt Mountains. The Little Belt Mountains exhibit broad, elevated, plateau-like areas that trend southeasterly.

The district is characterized by rugged mountains which rise steeply on both sides of Galena Creek. Elevations in the area range from 5,420 feet at the mouth of Galena Creek to 7,952 feet at Mixes Baldy Mountain (Figure 1-3). Most of the watershed is forested with the exception of the lower area near the confluence of Galena and Dry Fork Belt Creek.

Most of the mines and prospects in the area are in the vicinity of the historic towns of Barker and Hughesville. These old mining camps are located in the narrow Galena Creek Valley which flows southward into the Dry Fork of Belt Creek about 10 miles east of

Monarch. The Galena Creek drainage contains several mine waste dumps, streamside tailings, and an abandoned mill site with two large tailings ponds.

The climate of the Hughesville/Barker Mining District has many features associated with the "continental" type. The majority of the area's 30 inches of annual precipitation occurs during the spring. Daytime temperatures in the summer are usually hot, but not humid, and average about 75° F. Summer thunderstorms occasionally produce high winds and hail. Arctic air masses typically invade the area each winter bringing snow and blizzards. Minimum temperatures generally range from -40 to 7° F.

1.4.2 Geology

Walter Weed of the U.S. Geological Survey studied and mapped the geology of the Little Belt Mountains (Weed, 1900). Weed describes the general structure of the Little Belt Mountain Range as a broad, dome-shaped uplift. Sedimentary rocks near the summit of the dome are nearly horizontal; those on the northern and eastern flanks dip steeply toward the plains. Numerous laccolithic domes obscure the simple folds of the uplift by further deforming the sedimentary beds, particularly about the margin of the range and immediately beyond it (Weed, 1900).

Laccolithic domes form the most prominent structural features of the mountains at Hughesville. Both Barker Mountain on the west and Mixes Baldy on the east (Figure 1-3) are of laccolithic origin with cores composed of granite porphyry (Weed, 1900). Between these mountains and around their edges are the uplifted remnants of older sedimentary rocks ranging in age from Cambrian to Cretaceous which dip away in all directions from the intrusive masses. Near the upper end of Galena Creek, a stock of syenite intruded igneous and sedimentary rocks. The degree of metamorphism of sedimentary rocks near the igneous intrusions is moderate. The zone of altered rocks rarely extends more than a few yards from the contact (Robertson, 1951).

The more important ore bodies of the district occur in fissure veins either in syenite or along its contact with the surrounding rocks. Other ore deposits occur as irregular

replacement deposits at or near the contact of granite porphyry with Carboniferous, Devonian, or Cambrian sedimentary formations (Robertson, 1951).

1.4.3 Soils

Detailed soil information for the Galena Creek drainage is not available. The only available regional soils information is contained in a Soil Conservation Service (SCS) soil survey (SCS, 1967). This survey was completed for the Judith Basin area of Montana. This soil survey was extended south to the national forest boundary as far as the drainage divide between Green Creek and Big Otter Creek.

Soils mapped along the boundary of the survey near the Galena Creek drainage were identified as belonging to the Hughesville-Duncom Complex. These soils are moderately deep to shallow, loam to clay loam soils over limestone bedrock. Vegetation associated with these soils consists of grass and forest cover.

Soils in the Hughesville/Barker Mining District would probably not be classified as Hughesville-Duncom Complex soils because bedrock parent materials in the district are different. Underlying bedrock in the Hughesville/Barker District is primarily composed of granite porphyry and syenite. Soils on granitic bedrock are characteristically shallow on steep slopes such as are present in the Hughesville/Barker District. Typical forest soils are moderately developed, have a thin organic horizon, a four to six-inch thick A Horizon, and exhibit pH's ranging from 4.5 to 6.5 standard units.

1.4.4 Surface Water

The primary surface water course in the PA study area is Galena Creek (Figure 1-3). Galena Creek flows for approximately three miles from its headwaters to its mouth at the Dry Fork of Belt Creek. The Galena Creek watershed is rugged and mostly forested except for a small alluvial flat near the mouth of Galena Creek. The drainage area of Galena Creek near its mouth is approximately six square miles. Galena Creek is generally perennial and flows on a narrow but relatively persistent floodplain.

Average flow in Galena Creek measured by DNRC (1977) is about two cubic feet per second (cfs). Measured flows ranged from 0.5 cfs to 13 cfs. Local landowners have reported that several large flood events have occurred in the Galena Creek drainage over the past 20 years. These phenomena are evident in the cobble-sized material which blanket portions of the active floodplain.

Water quality in the Galena Creek drainage is degraded by discharge from abandoned mine shafts and adits, leachate from mine/mill waste and tailings dumps, and erosion of mine waste and disturbed areas. DNRC (1977) data indicate Galena Creek near its mouth contains very poor water quality and exceeds several primary and secondary drinking water standards and ambient water quality criteria. Galena Creek and a portion of the Dry Fork of Belt Creek below Galena Creek do not support aquatic life. Acid mine drainage entering Galena Creek from multiple sources is the probable cause of the lack of an aquatic community in the streams.

Galena Creek empties into the Dry Fork of Belt Creek (Figure 1-3). Water in Dry Fork of Belt Creek above its confluence with Galena Creek is of good quality. No exceedances of either drinking water standards or aquatic criteria have been measured in this reach of the stream. The quality of water in the Dry Fork of Belt Creek degrades measurably below its confluence with Galena Creek.

Suspended solids contained in runoff water are likely derived from areas disturbed by mining in the Galena Creek drainage and the tailings ponds at the mill site near the mouth of Galena Creek.

The Dry Fork of Belt Creek empties into Belt Creek near the town of Monarch. A viable fishery is reportedly present in Belt Creek below the Dry Fork. Belt Creek flows into the Missouri River approximately 10 miles northeast of Great Falls.

1.4.5 Groundwater

Minimal information is available regarding the groundwater resources of the Hughesville/Barker Mining District. The district hosts several discharging adits and springs which provide some information on the groundwater system in the area. The hydraulics and quality of groundwater in the area's bedrock system is likely controlled by the presence or absence of fractures and by the extensive network of mine tunnels associated with the district.

Galena Creek flows on a narrow floodplain which likely hosts a relatively small alluvial groundwater system. The interrelationships between Galena Creek and the alluvial groundwater system were investigated during this PA.

A landowner near the town of Barker does not consume water obtained from her domestic well because of water quality concerns (Ms. Gwen McBride, personal communication, September, 1990). This well is reportedly completed in fractured bedrock near an altered stratigraphic zone. Such information may suggest that naturally contaminated groundwater may be present in the study area. Additional groundwater information was obtained during this preliminary assessment. Results of this effort are presented in Section 4.0 of this report.

1.5 PROJECT OBJECTIVES

General objectives in completing a PA at the Hughesville/Barker Mining District included the following:

- ♦ Collect and collate baseline information to efficiently plan and conduct more comprehensive site investigations and evaluations of reclamation alternatives which fully address the requirements of the NCP, NEPA, and MEPA.
- ♦ Provide preliminary identification of operable units within the study area.

- ◆ Provide a rational basis to prioritize subsequent reclamation activities within the study area.

2.0 SUMMARY OF EXISTING INFORMATION/DATA

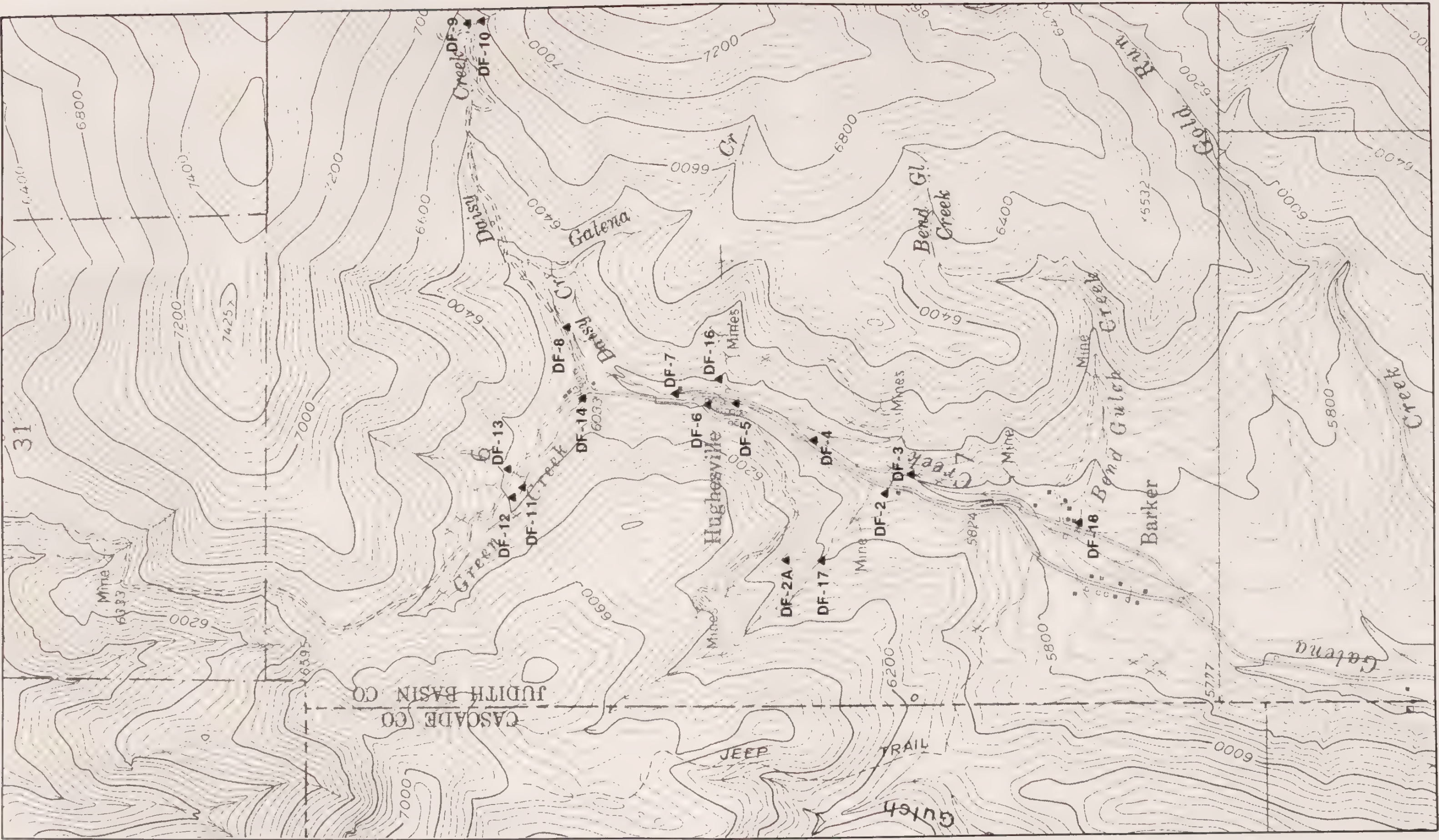
Existing environmental information/data for the Hughesville/Barker Mining District area include surface water data collected by the Montana Department of Natural Resources and Conservation (DNRC), reclamation plans developed for the AMRB for certain portions of the study area, and historic mine maps and mining/milling descriptions for several of the larger mining operations in the area. Chen-Northern personnel sought other existing information concerning other aspects of the study area from various local and state agencies and through contact with area residents. Available information resulting from this task was collated and summarized in this section.

2.1 SURFACE WATER DATA

2.1.1 DNRC Data

The DNRC completed streamflow measurements at five stream gaging stations located on Galena Creek both upstream and downstream of the Block P Mine dump. DNRC personnel also periodically obtained other flow measurements at certain adit and spring discharges. The DNRC obtained daily streamflow records at five stream gaging stations in the area from September, 1973 to November, 1974 and between April and October of 1976. Hydrologists also gathered streamflow data from as many as 26 other water quality sampling stations in and near the study area between May, 1973 and October 1977. DNRC personnel measured streamflows monthly at seven of the sampling stations during that period and infrequently at the balance of the sampling stations. Sampling locations used by DNRC are illustrated on Figure 2-1.

DNRC hydrologists collected surface water samples monthly from seven water quality sampling stations in the study area between May, 1973 and October, 1977. An additional 24 stations were sampled at least once during that period. The Montana Water Quality Bureau laboratory in Helena performed all water quality analyses for the DNRC. Table 2-1 summarizes parameters analyzed in most samples obtained during the various sampling episodes completed by the DNRC.



Surface Water Sampling Sites
Used by the DNRC (1973-1977)
FIGURE 2-1 (sheet 1 of 2)

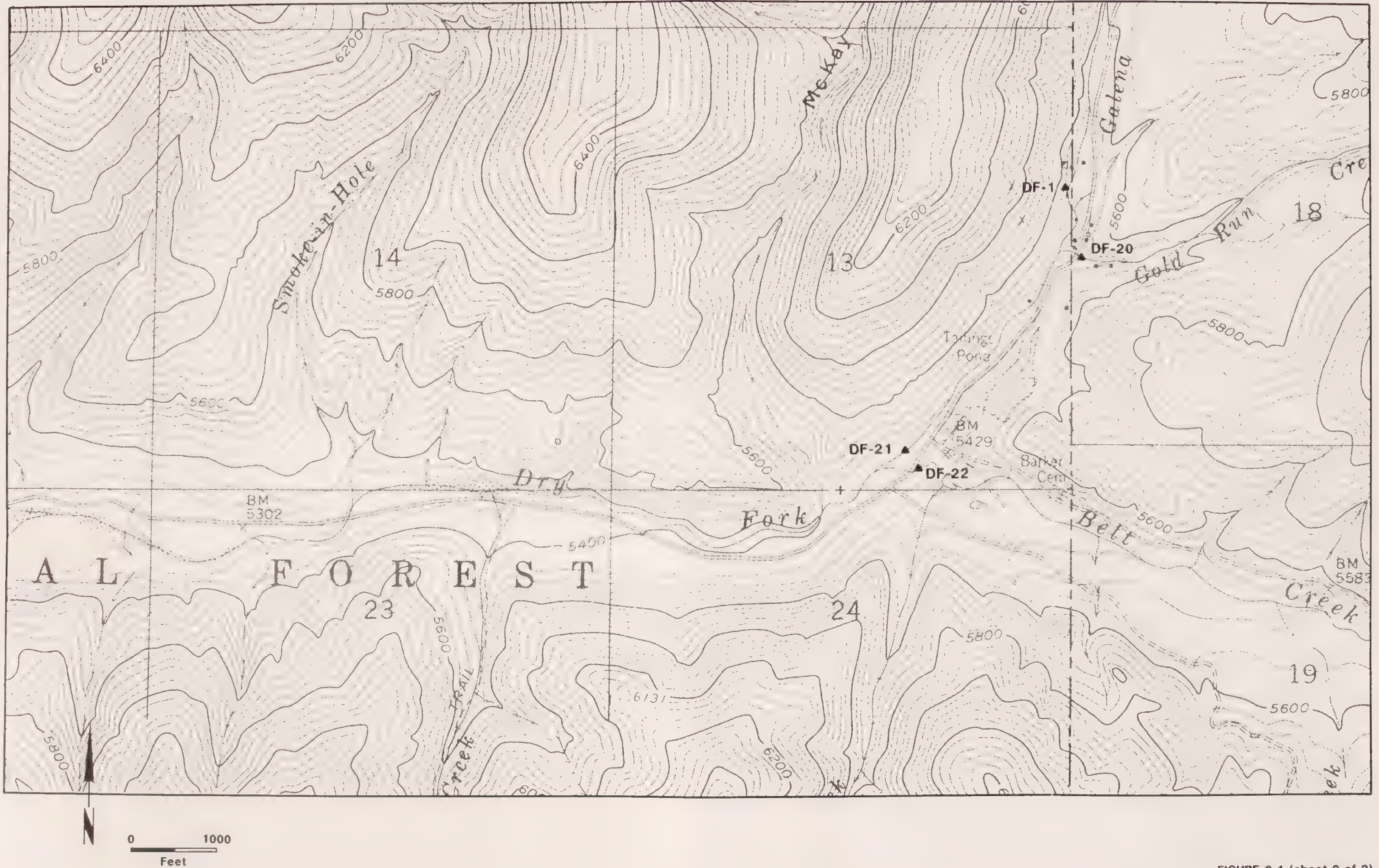


FIGURE 2-1 (sheet 2 of 2)

TABLE 2-1
SUMMARY OF PARAMETERS ANALYZED BY THE DNRC⁽¹⁾

Temperature	Hardness	Arsenic
pH	Acidity (as CaCO ₃)	Aluminum (TR, D)
Specific Conductance	Sodium Adsorption Ratio (SAR)	Cadmium (TR,T,D)
Turbidity	Calcium	Copper (TR,D)
	Magnesium	Iron (TR,T)
	Potassium	Lithium (T,D)
	Sodium	Manganese (TR,T)
	Chloride	Mercury (TR,T,D)
	Fluoride	Silver (TR,T,D)
	Sulfate	Selenium (TR,D)
		Zinc (TR,D)

1. TR = Total Recoverable; T = Total; D = Dissolved

The DNRC evaluated water quality data generated from samples obtained between 1973 to 1977. Based on these analyses, several conclusions were made which are presented in DNRC (1977):

- ♦ Water quality in Galena Creek and the Dry Fork of Belt Creek is significantly influenced by acid mine discharge from old lead and silver mines. The mechanism for producing acid involves interaction of pyritic minerals, oxygen, and water. Metals which enter Galena Creek system via this mechanism include cadmium, zinc, iron, manganese, lead, copper, arsenic, and aluminum.
- ♦ Water quality in the Galena Creek drainage is extremely poor at the Liberty Mine seep, a spring at the Block P Mine, and a spring in Galena Creek near some abandoned mine cars. These sources exert a significant influence on the overall quality of water in Galena Creek.

- ◆ The water quality is better in the Dry Fork of Belt Creek below Galena Creek and in Galena Creek above the mining area, but the water is still toxic to most aquatic life.
- ◆ Concentration of toxic metals in the streams is not significantly diluted by rainfall or melting snow.
- ◆ The Block P Mine dump is a major source of pollutants to Galena Creek.

2.1.2 DSL Data

Data analyzed for the DSL Reclamation and Development Grant included water quality samples gathered from three stations located below the Block P Mill tailings pond. Samples were collected on May 31, 1979 and October 22, 1979 at the mouth of Galena Creek and on Dry Fork of Belt Creek above and below the mouth of Galena Creek. Parameters analyzed in these samples included pH, specific conductivity, sulfate, and four metals.

Conclusions presented in DSL (1988) include the following:

- ◆ Water quality in the Galena Creek drainage is significantly degraded by discharge from abandoned mine shafts and adits, leachate from mine/mill waste and tailings dumps, and erosion of mine waste and disturbed areas.
- ◆ Water quality in Galena Creek near its mouth is very poor, exceeding the minimum primary and secondary values of drinking water standards and those values recommended for a viable fishery.
- ◆ Water quality in Dry Fork of Belt Creek above its confluence with Galena Creek meet all drinking water standards and do not contain concentrations of heavy metals which adversely affect fish and aquatic life.

- ◆ Water quality in the Dry Fork of Belt Creek degrades significantly below its confluence with Galena Creek.
- ◆ Zinc concentrations in Galena Creek and the Dry Fork of Belt Creek exceed EPA "Gold Book" criteria for a viable fishery.

2.2 PREVIOUS RECLAMATION EVALUATIONS

Two studies of reclamation alternatives of the Galena Creek area were previously completed. One study included an evaluation of reclamation alternatives by the DNRC which was guided by their data collection efforts described previously. The other study was completed by the DSL to devise a means of reclaiming the Block P Mill tailings near the mouth of Galena Creek.

2.2.1 DNRC Studies

The DNRC studies were conducted between 1973 and 1978. During that period, both a feasibility study (DNRC, 1977) and demonstration project (DNRC, no date) were completed to investigate silver-lead mine waste manipulation for acid mine drainage control. The feasibility study and demonstration project attempted to:

- (1) identify acid mine drainage problems in Galena Creek and the Dry Fork of Belt Creek,
- (2) document water quality conditions at that time,
- (3) recommend abatement methods, and,
- (4) demonstrate mitigation measures at the Block P Mine dump.

The reclamation efforts resulting from this study focused on reshaping the top of the Block P Mine dump and isolating Galena Creek from the mine dump. The top of the mine

dump was back-sloped into the adjacent hillside and covered with both low-permeability material and topsoil. The intent of implementing this slope configuration was to direct surface runoff around the mine dump to minimize infiltration into the waste dump.

Galena Creek was routed through a culvert around the Block P Mine dump and was allowed to reenter the existing channel below the deposit. The impact of this reclamation activity on the quality of Galena Creek was also monitored following construction.

Results of the post-reclamation monitoring indicated no significant improvement occurred as a result of the reclamation efforts. The surface water diversion system eventually washed out and was abandoned. The reshaped surface of the top of the mine dump currently supports a viable stand of vegetation.

2.2.2 DSL Studies

The DSL study (DSL, 1988) was initiated to support an application for a Reclamation and Development Grant from the DNRC. This grant application was submitted to the DNRC by the AMRB in May, 1988. The purpose of the proposed reclamation project was to remediate off-site impacts emanating from the Block P mill tailings ponds near the mouth of Galena Creek.

The plan developed by DSL for the Block P mill tailings included the following components:

- ◆ Grading and sloping the mill tailings.
- ◆ Installing drainage ditches.
- ◆ Reclaiming and revegetating disturbed areas.

The stated objectives of the grant application for the project were to improve water quality in Galena Creek and the Dry Fork of Belt Creek and improve the aesthetics of the area. This project was not funded by the 1989 Montana legislature.

2.3 DEMOGRAPHIC DATA

Currently, five year-round residents and several persons with summer homes reside in the PA study area for the Barker/Hughesville Mining District. The year-round residents live in the historic Barker townsite (Figure 2-2). The Barker community presently consists of approximately 20 log and frame structures which comprise the remains of the townsite.

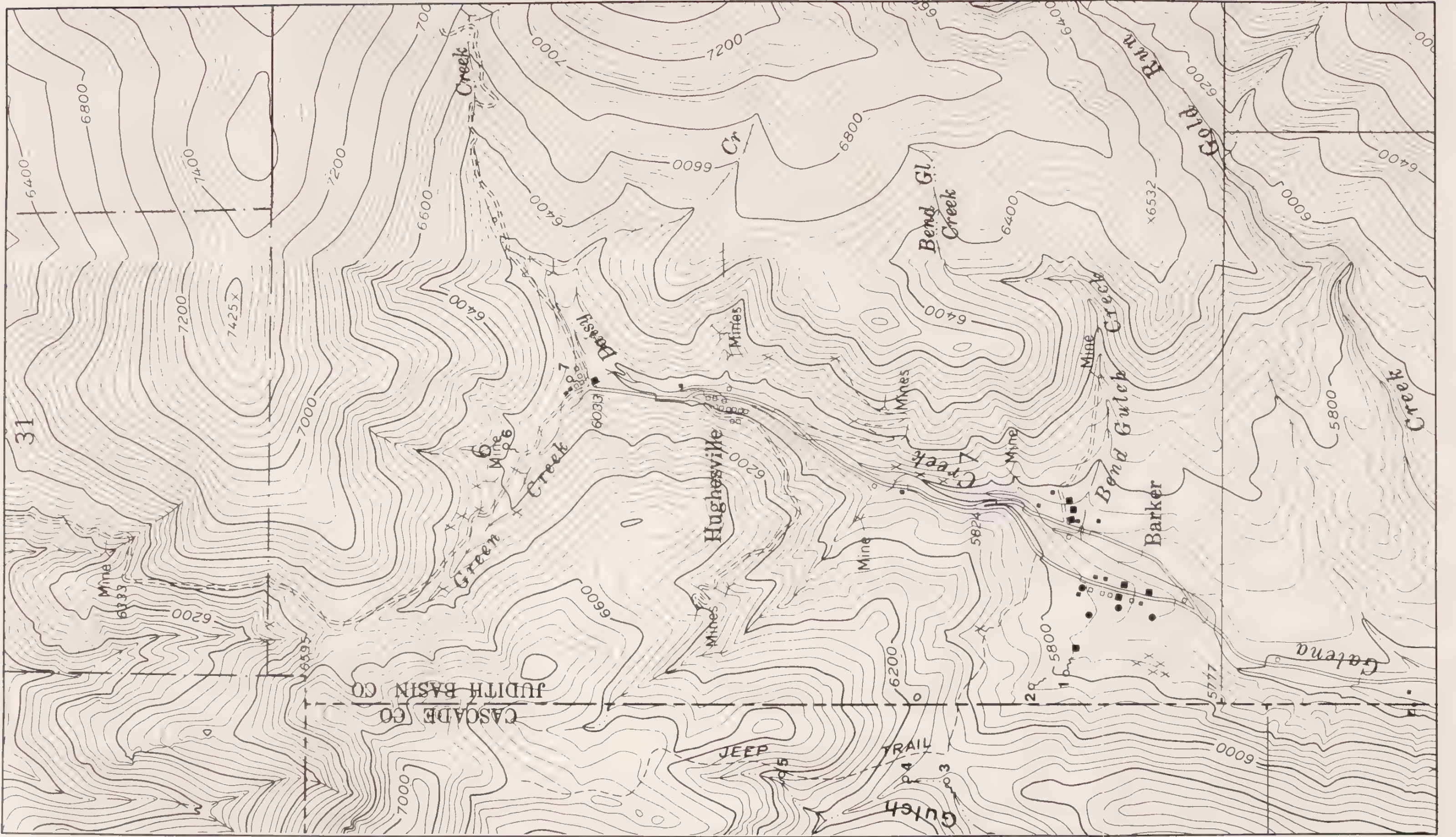
Seasonal residents have homesites in Barker, adjacent to Gold Run Creek, and near the confluence of Galena Creek and Green Creek (Figure 2-2). The Barker Community Hall serves as the cultural center for all area residents and others with historic ties to the area.

2.4 LAND USE

Land use in the Barker/Hughesville Mining District has changed from mining to timber harvesting, livestock grazing, and recreation. Most of the Galena Creek watershed is forested with the exception of areas in the lower reaches of the stream near the confluence of Galena Creek and the Dry Fork of Belt Creek. Timber harvesting in the form of clear cutting has taken place on the southern slopes of Anderson Peak, and along the headwaters of Dry Fork of Belt Creek.

Forested areas of the Belt Creek drainage are a major recreational resource for residents of Great Falls and Malmstrom Air Force Base. The nearby towns of Monarch and Neihart are resort communities which depend on the fishing, hunting, camping, skiing, snowmobiling and hiking opportunities the area offers for their livelihood.

Mining was the primary land use of the study area between 1890 and 1940. Currently, one small mining venture involving three tunnel sites operates seasonally in the upper Galena Creek drainage. Unpatented claimants are also involved in annual assessment work.



- Permanent/Seasonal Residence
- Spring
- Domestic Well

Residences, Domestic Wells, and Springs
Hughesville/Barker Mining District
FIGURE 2-2 (sheet 1 of 2)

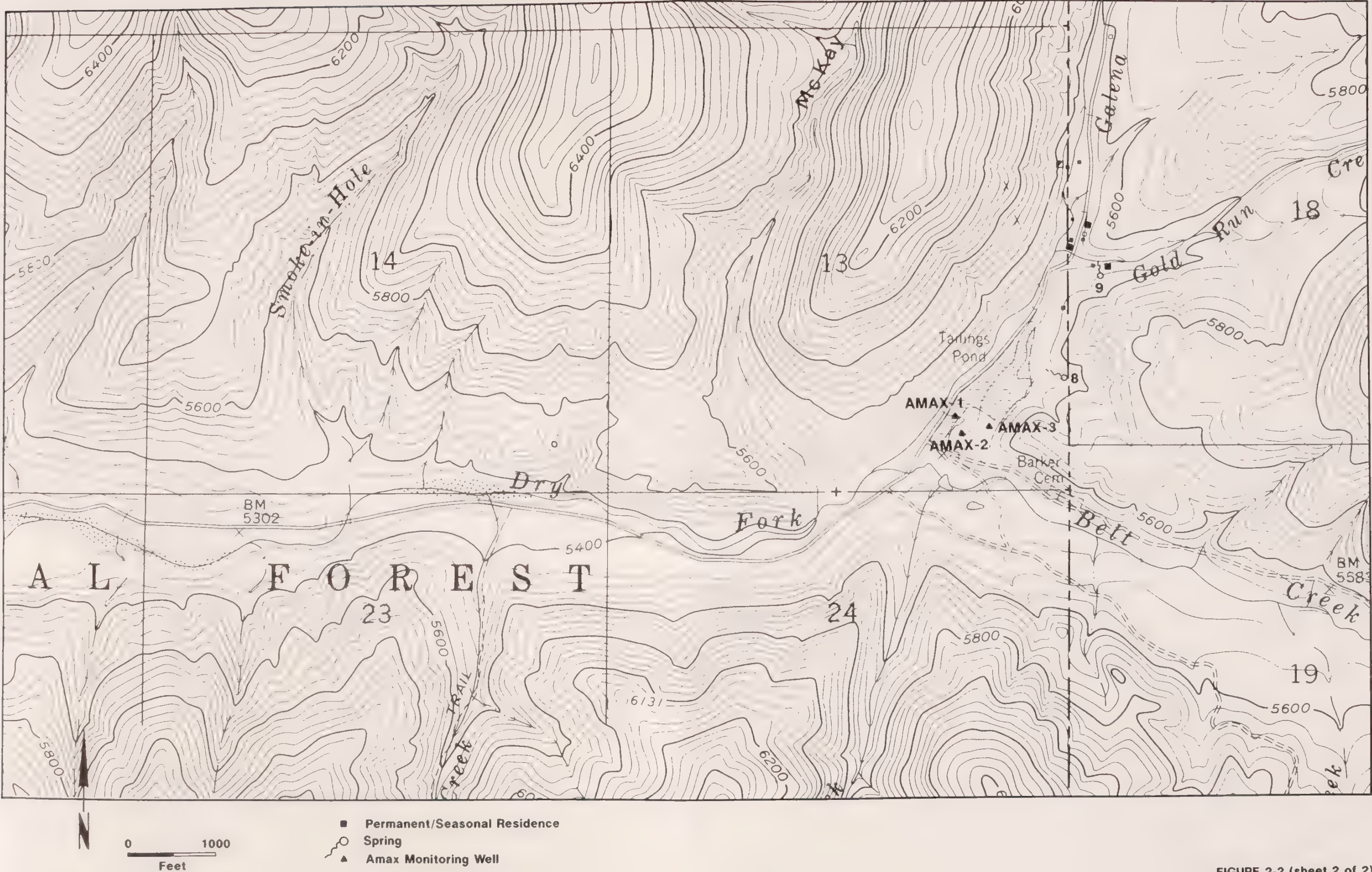


FIGURE 2-2 (sheet 2 of 2)

2.5 LAND OWNERSHIP

Land ownership in the Galena Creek drainage consists of patented mining claims whose surface and mineral rights are privately owned and public land administered by the Lewis and Clark National Forest. Much of the public land of economic interest has been staked by claimants who perform annual assessment work to maintain claims on mineral rights. Of the approximately 5,000 acres which comprise the study area, 1,500 acres are private patented claims.

The principal patented claim owners in the Judith Basin County portion of the study area are listed in Table 2-2. Table 2-2 also summarizes the approximate acreages these persons own.

TABLE 2-2
PRIVATE LANDOWNERSHIP IN THE HUGHESVILLE/BARKER MINING DISTRICT

PRIVATE LANDOWNERS	ACREAGE OWNED
Pava Borgan, William & Franklin Davis	291
Gwen Vaughan-Rhys McBride	204
Harry Anderson & Pete Antonioli (Emerald Resources)	184
Lera Dell Westerman	183
George Croff	78
Tobin Estate	62

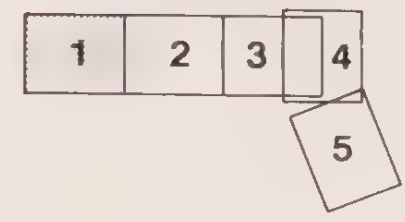
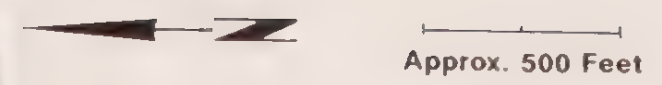
2.6 EXTENT OF MINE WASTES

The mine wastes located throughout the Barker/Hughesville Mining District can be classified according to three types; mine dumps, mill tailings, and streamside tailings. Historical reports describe smelters which operated in the district. To date, no smelter slag has been identified in the study area.

Waste dumps constitute the material extracted from development of tunnels and shafts. Most of these wastes are located on the steep side slopes of the Galena Creek valley (Figure 2-3). Based on work completed during this PA, the total volume of mine dump waste in the Galena Creek drainage is estimated to be 500,000 cubic yards.

The Block P millsite (Figure 2-3) is the primary source of mill tailings in the study area. The historic millsite is located on the east side of Galena Creek near its confluence with the Dry Fork of Belt Creek. This site was used for over 50 years for various milling operations which have taken place in the district. Based on limited data collected during this PA, approximately 500,000 cubic yards of tailings are present at the Block P millsite. The tailings occupy an area of approximately 15 acres.

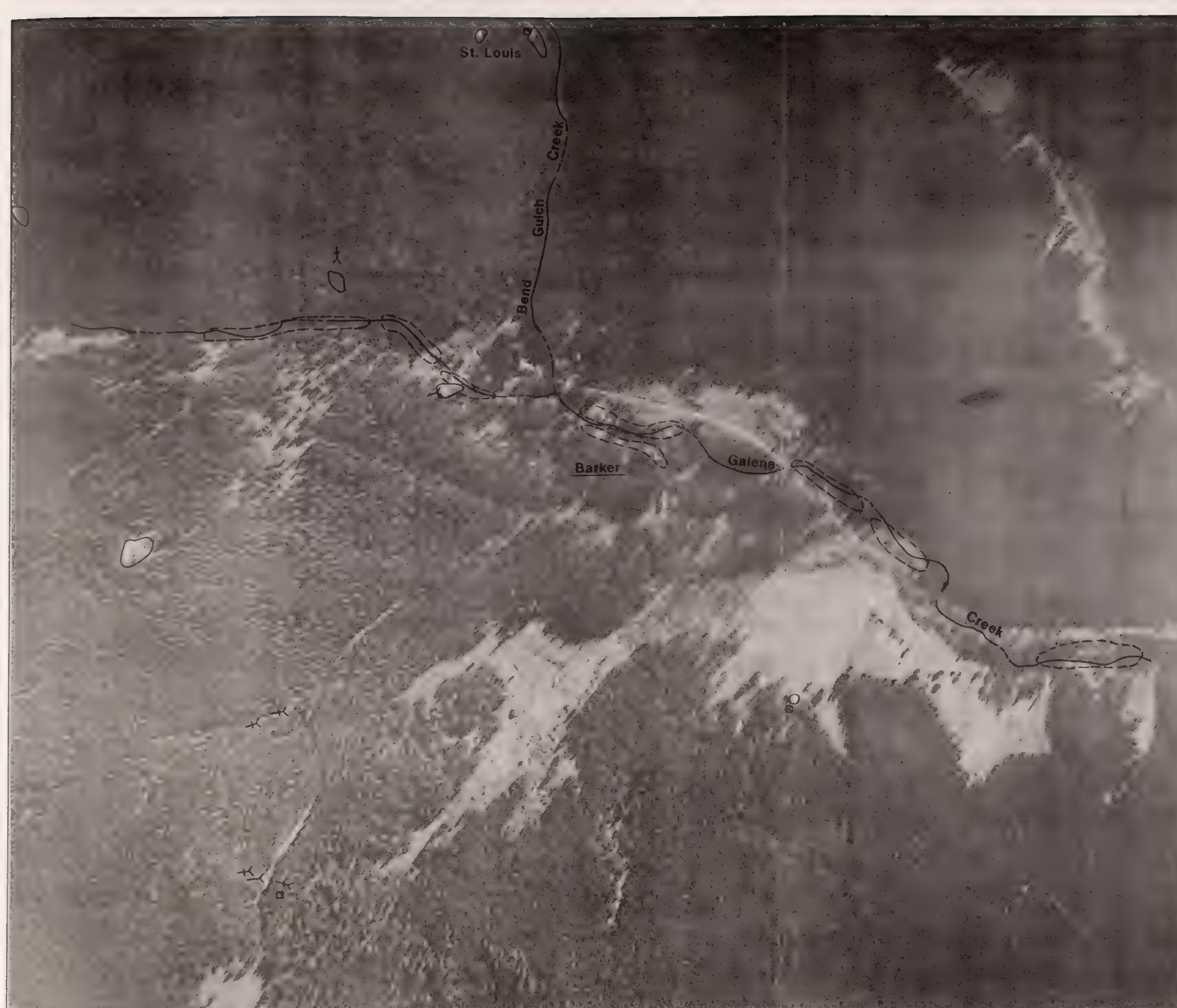
Streamside tailings are the third type of mine waste material present within the PA study area. This material consists of tailings and waste rock which have been eroded and transported from source areas by runoff and surface water courses and redeposited in and along area stream channels. This material is most obvious as denuded areas in the floodplain along the middle reaches of Galena Creek and the reach of Dry Fork of Belt Creek near its confluence with Bender Creek (Figure 2-3). Streamside tailings in the project study area range in depth from less than one inch to five feet. The volume of this material is unknown.



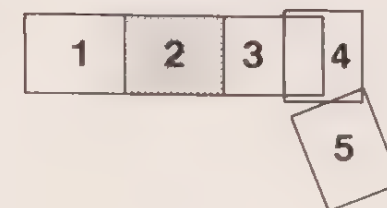
- Adit
- Caved Adit
- Shaft
- Caved Shaft
- Waste Rock Dump
- Streamside Tailings



Adits, Shafts, and Mine and Mill Waste Deposits
Hughesville/Barker Mining District
FIGURE 2-3 (sheet 1 of 5)



Approx. 500 Feet









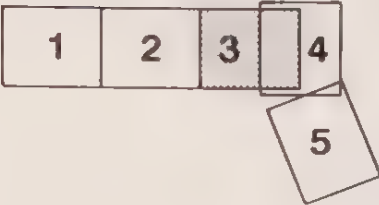
-  Adit
-  Caved Adit
-  Shaft
-  Caved Shaft
-  Waste Rock Dump
-  Streamside Tailings

FIGURE 2-3 (sheet 2 of 5)

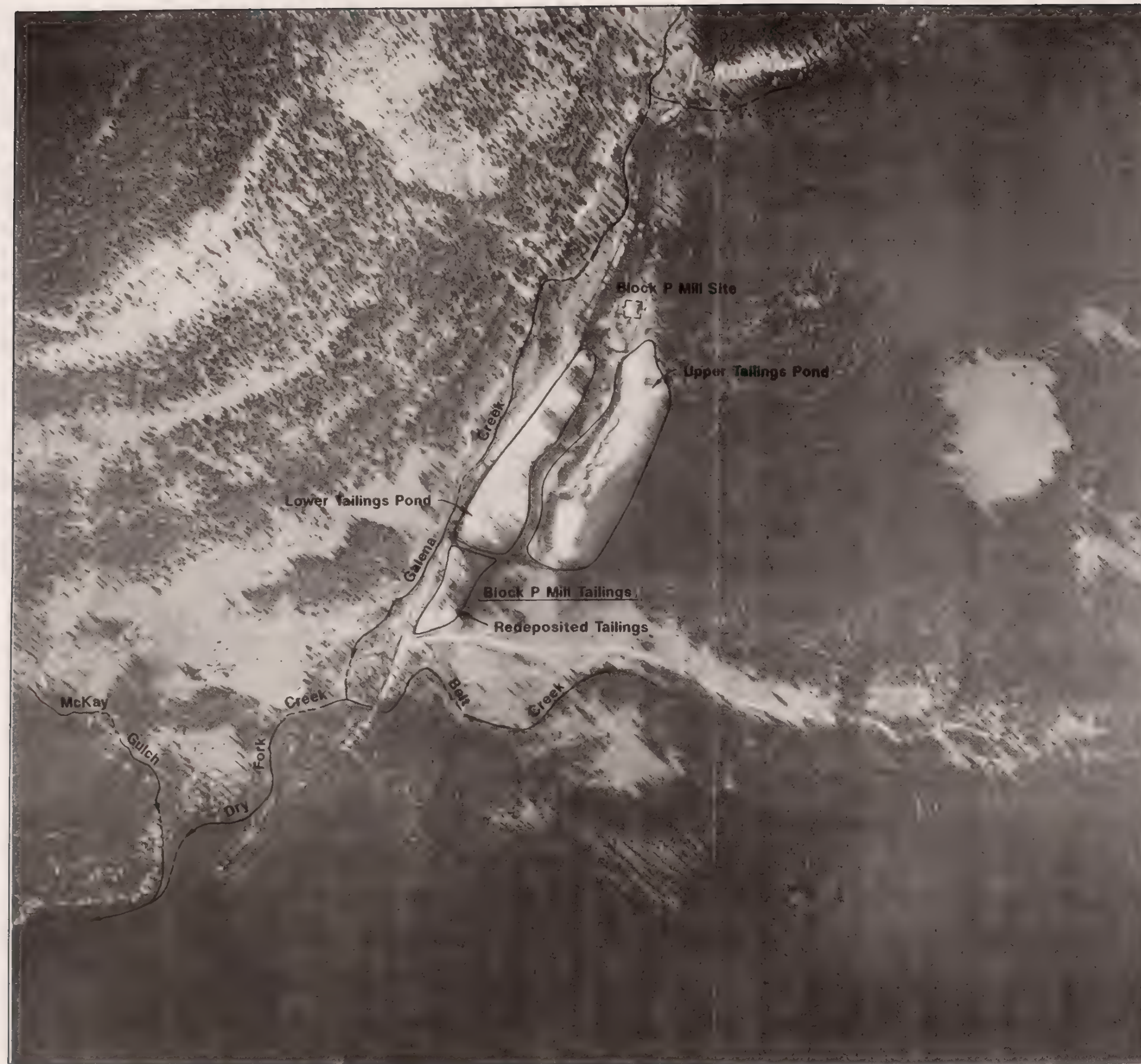


Approx. 500 Feet

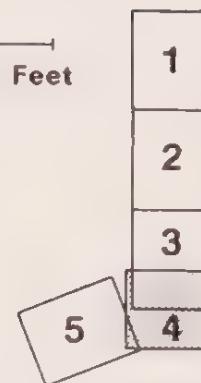


- Y Adit
- Y Caved Adit
- Shaft
- ⊠ Caved Shaft
- Waste Rock Dump
- Streamside Tailings

FIGURE 2-3 (sheet 3 of 5)



Approx. 500 Feet









-  Adit
-  Caved Adit
-  Shaft
-  Caved Shaft
-  Waste Rock Dump
-  Streamside Tailings

FIGURE 2-3 (sheet 4 of 5)



- Y Adit
- Y Caved Adit
- Shaft
- ⊠ Caved Shaft
- Waste Rock Dump
- Streamside Tailings



FIGURE 2-3 (sheet 5 of 5)

2.7 ADIT AND SHAFT LOCATIONS

Adits and shafts were historically utilized throughout the study area to explore and develop metallic ore bodies. Many of these mine openings are now collapsed at the portals, prohibiting entry. Known adit and shaft locations in the study area are shown on Figure 2-3.

2.8 DOMESTIC WELL AND SPRING INVENTORY

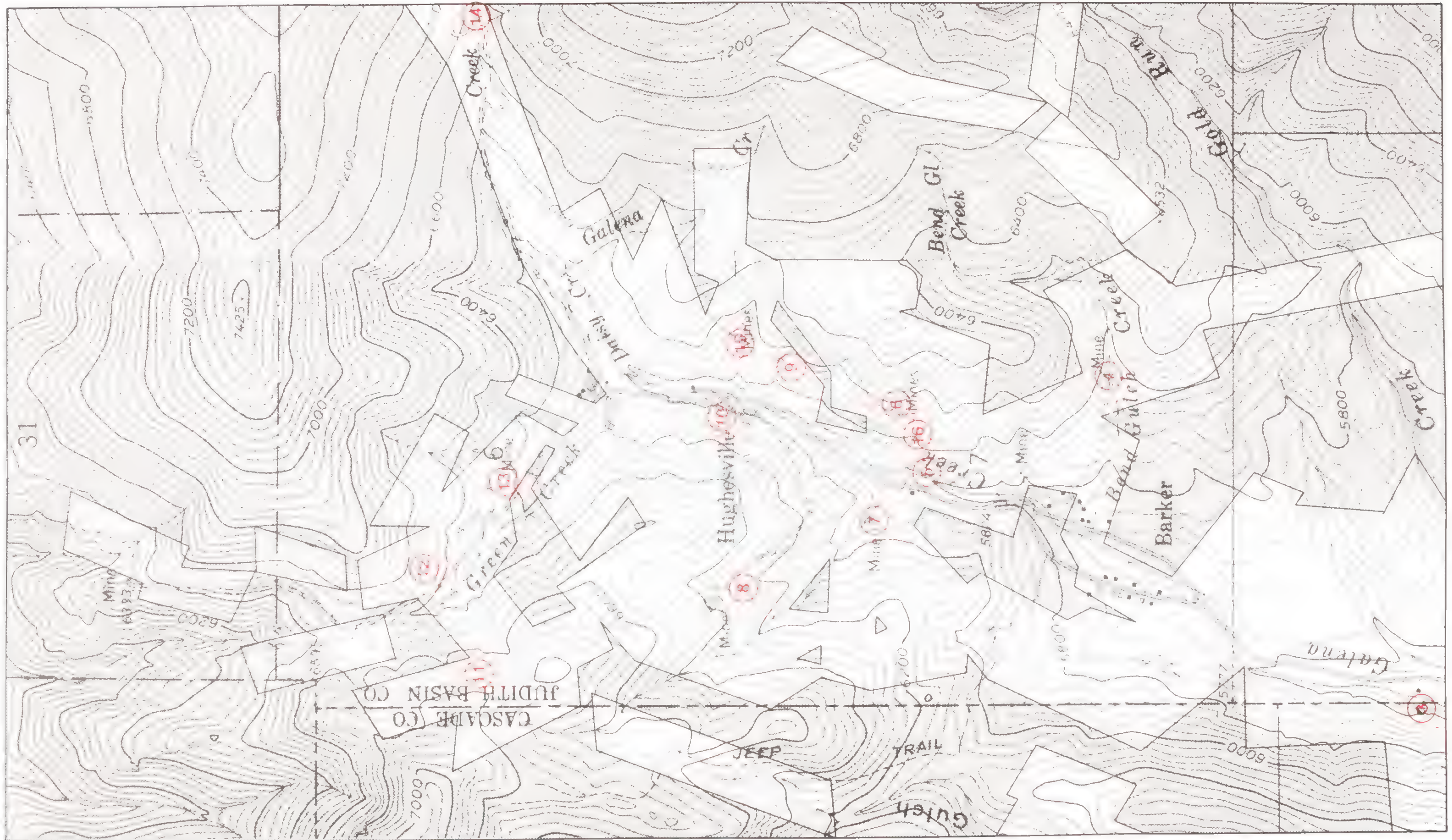
Domestic wells and springs in the study area were located and inventoried as part of this PA. Figure 2-2 shows the locations of domestic wells and springs identified in the study area. Four domestic wells are located within the study area, all in the vicinity of Barker.

Information was available for only one of the four wells identified in the study area. This domestic well, located in Barker, is reportedly 40 feet deep and is completed in an altered zone. This well was sampled during the PA. Results of the laboratory analysis are discussed in Section 4.0. Other domestic wells in the Barker area were not sampled due to limitations of accessibility.

The occurrence of springs in the Galena Creek drainage is likely controlled by the presence of faults, contacts, or fractures. Nine springs were identified during the inventory. Five of these springs are located on the west side of the Galena Creek Valley, two are located above Green Creek, one is located above Gold Run Creek, and one is present above the Block P millsite (Figure 2-2).

2.9 MINERAL OWNERSHIP

The mineral ownership within the Barker/Hughesville Mining District consists of patented claim owners, the U.S. Forest Service, and unpatented claimants. Table 2-3 summarizes the mineral ownership of the significant mines and millsites in the study area. The location of these sites is shown on Figure 2-4.



0 1000
Feet

- 3. Silver Bell Mine
- 4. St. Louis Mine
- 5. Marcelline Mine
- 6. Liberty Mine
- 7. Defiance Mine

- 8. Wright & Edwards Mine
- 9. Doctor Kollach Mine
- 10. Block P Mine
- 11. May & Edna Mine
- 12. Paragon Mine

- 13. Carter Mine
- 14. Moulton Mine
- 15. Queen of the Hills Mine
- 16. Danny T Mine

- Patented Claims
- Public Lands

Patented Claims and Public Lands
Hughesville/Barker Mining District
FIGURE 2-4 (sheet 1 of 2)

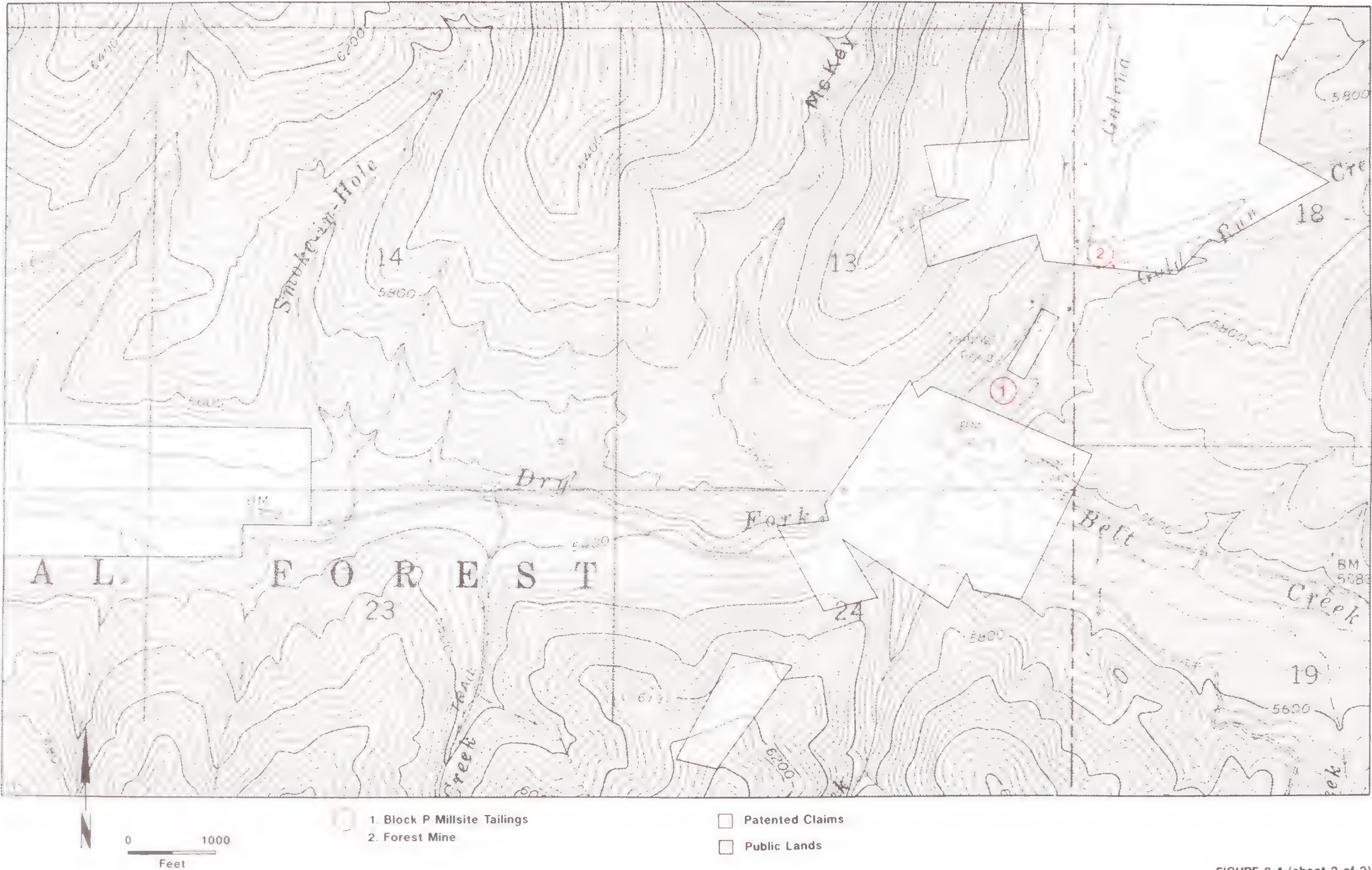


FIGURE 2-4 (sheet 2 of 2)

TABLE 2-3
MINERAL OWNERSHIP IN THE HUGHESVILLE/BARKER MINING DISTRICT

LOCATION*	MINE/MILL SITE	PATENTED CLAIMS & PUBLIC LAND	MINERAL OWNERSHIP
1	Block P Millsite	Private (Millsite & Toliver Placer) i Public	Anderson, Antonioli, & McBride; USFS
10	Block P Mine	Private (Barker & Gray Eagle)	Anderson & Antonioli
13	Carter Mine	Private (Carter)	Borgan, Davis & Davis
7	Defiance Mine	Private (Carter)	Anderson, Antonioli, McBride & Tobin
9	Doctor Kollock Mine	Private (Doctor Kollock)	Zupan
2	Forest Mine	Private (Forest)	Morton, Stoos & Winterrowd
6	Liberty Mine	Private (Danny T & Liberty)	Anderson, Antonioli, McBride & Tobin
5	Marcelline Mine	Private (Annie E & Marcelline)	Anderson, Antonioli, McBride & Tobin
11	May & Edna Mines	Private (May & Edna)	McBride
14	Moulton Mine	Private (Moulton)	Croff
12	Paragon Mine	Private (Paragon)	Borgan, Davis & Davis
4	St. Louis Mine	Private (Magnolia & St. Louis)	Westerman
3	Silver Bell Mine	Private (Silver & Bell)	Borgan, Davis & Davis
8	Wright & Edwards Mine	Private (Wright & Edwards)	Anderson & Antonioli

* Locations shown on Figure 2-4

3.0 SURFACE WATER INVESTIGATION

In this section, methods used to collect surface water data during this PA are described. We also describe changes to the project sampling and analysis plan resulting from implementation of the surface water data collection task and present and interpret collected data. Where appropriate, data collected during this PA are compared and contrasted to surface water data previously collected by DNRC (1977).

3.1 METHODS

Chen-Northern field scientists completed several surface water work tasks in conjunction with this PA. These included selecting sample and flow measurement sites, completing synoptic flow measurements, and sampling. Methods to complete these tasks are described below.

3.1.1 Sampling/Flow Measurement Site Selection

Hydrologists completed two general types of activities to collect information germane to surface water resource characterization in the study area. These included gathering synoptic flow measurements (a seepage run) at several sites within the study area and sampling surface water at a subset of the seepage run sites. Locations of both the seepage run sites and sampling sites are shown on Figure 3-1.

Chen-Northern field scientists selected sites for the seepage run to determine the influent-effluent characteristics of Galena Creek. The purpose of this effort was to ascertain the interrelationship between the area's surface water and groundwater systems. Flow data gathered during this endeavor were used in conjunction with groundwater data (described in Section 4.0) to characterize the hydrologic environment in the study area.

Sites selected for seepage run measurements were located to generally bracket various reaches of Galena Creek where geomorphic evidence suggested the stream would either gain or lose flow. This evidence generally consisted of a broadening of the valley bottom



- △ Surface Water Gaging Station
- ▲ Surface Water Sampling and Gaging Station



Surface Water Gaging and Sampling Stations
Galena Creek Preliminary Assessment
FIGURE 3-1 (sheet 1 of 2)

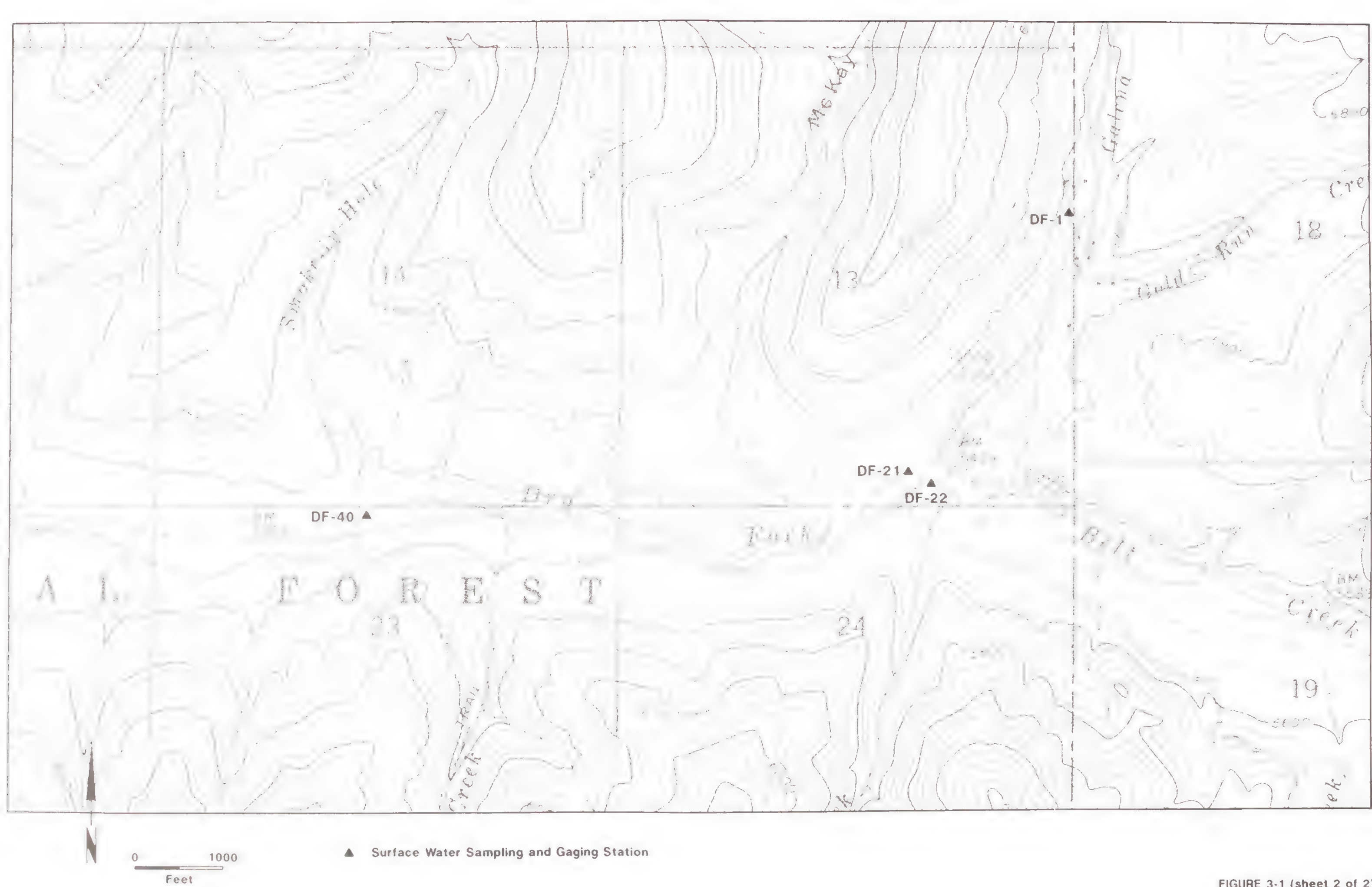


FIGURE 3-1 (sheet 2 of 2)

or the presence of groundwater discharge areas (e.g. swamps, bogs). All major tributary inputs to Galena Creek were also included as flow measurement sites for incorporation into the data analysis.

Chen-Northern scientists also selected surface water sampling sites to generally bracket major areas within the drainage which exhibited evidence of mining disturbance. Major tributaries to Galena Creek were sampled to provide analytical data for evaluation of impacts to receiving streams. Our personnel selected other sampling sites on the Dry Fork of Belt Creek to determine water quality parameters above and below its confluence with Galena Creek.

3.1.2 Streamflow Gaging

A Chen-Northern hydrologist measured discharge at each seepage run measurement site and at each sampling site using one of two methods, current meter measurements or time-volume measurements. The field person used a pygmy-type current meter at gaging sites which contained sufficient flow to warrant use of such a device. At sites which contained minimal flow and where the depth of water was shallow, the hydrologist estimated discharge.

Field personnel entered all field data and notes in a project notebook or on forms developed specifically for stream gaging. We reduced the resulting flow data in the field to check for inaccuracies or inconsistencies. The project hydrologist further checked the data to insure the data reduction process was accurate.

3.1.3 Sampling

Field crews collected surface water samples at 15 sites within the study area (Figure 3-1). A description of each sampling site is presented in Table 3-1. Samples were collected from Green Creek, Galena Creek, and the Dry Fork of Belt Creek.

TABLE 3-1
DESCRIPTION OF SURFACE WATER SAMPLING SITES;
GALENA CREEK PRELIMINARY ASSESSMENT

STATION NUMBER	WATER QUALITY SAMPLING POINTS
DF-01	Galena Creek at Lower Weir
DF-02	Silver Creek at Mouth
DF-03	Liberty Mine Seep at Galena Creek
DF-04	Galena Creek just below Mine Dump
DF-05A ^(a)	Galena Creek at Mine Dump Face
DF-05	Galena Creek above spring at Mine Cars
DF-06A ^(a)	Galena Creek at Bubbling Spring at Block P Mine
DF-07	Galena Creek at Upper Weir
DF-08	Galena Creek near Harrison Mine above Green Creek Input
DF-14	Green Creek above Mouth at Galena Creek
DF-21	Galena Creek above Belt Creek Confluence
DF-22	Belt Creek at Mouth
DF-40	Galena Creek above Smoke-in-Hole Creek Confluence
DF-45	Queen of the Hills at Portal (also known as DF-16)
DF-46	Galena Creek below the Block P Dump at Streamside Tailings
DF-47	Galena Creek West of Road below Barker Townsite
DF-48 ^(a)	Galena Creek above Bend Gulch Creek
DF-49	Carter Mine at Portal

(a) Gaging station only

The field crew collected samples immediately after discharge was measured at each sample site. Hydrologists used a DH-48 sampler to collect samples at sites which contained sufficient flow and stream depth to warrant use of the sampler. At sites where the DH-48 sampler was used, an equal discharge interval (EDI) sampling technique was employed. This method involves dividing the stream into three or four segments of equal discharge, sampling an equal volume of water from each segment, and compositing the portions into a single container. The EDI sampling method results in a flow- and depth-integrated sample which is representative of the total volume of water at a sample site. Such a sampling method is desirable at locations which may be impacted by point- and/or line-source inputs.

Grab sampling was completed at sites which exhibited minimal flow. This sampling method involves collection of the sample at the midpoint of the water course or at several points across the stream, typically in the portions of the stream which contains the highest velocity. The sample container is submerged to a point just below the water surface. Multiple grab samples at each site are composited to collect a single sample.

Field parameters including pH, specific conductance, and temperature were measured in each collected sample immediately following retrieval. These data were entered on a field form. Collected samples were split into four polyethylene bottles. Samples were prepared and preserved (as necessary) in accordance with current EPA guidance for such procedures. Samples collected for dissolved metals analysis were field-filtered through a 0.45 micron filter. Samples collected for both total and dissolved metals were preserved with 2-3 milliliters (ml) of reagent grade nitric acid. Samples collected for nutrients analysis were preserved with 2-3 mls of reagent grade sulfuric acid and placed in an ice-filled cooler. Samples collected for common ions were preserved on ice in a cooler. Table 3-2 summarizes the surface water parameter list for this PA.

TABLE 3-2
SURFACE WATER PARAMETER LIST;
GALENA CREEK PRELIMINARY ASSESSMENT

FIELD PARAMETERS

Temperature
pH
Eh
Specific Conductivity

LABORATORY PARAMETERS

	<u>Metals (Total and Dissolved)</u>
Temperature	Aluminum
pH	Arsenic
Specific Conductivity	Barium
Total Dissolved Solids	Cadmium
Sodium Adsorption Ratio	Chromium
Total Hardness as CaCO ₃	Copper
Calcium	Iron
Magnesium	Lead
Sodium	Manganese
Potassium	Mercury
Total Alkalinity as CaCO ₃	Nickel
Bicarbonate Alkalinity as HCO ₃	Selenium
Carbonate Alkalinity as CO ₃	Silver
Hydroxide Alkalinity as OH	Zinc
Chloride	
Fluoride	
Nitrate + Nitrite as N	
Sulfate	

Quality control samples were incorporated into the sample train in accordance with the project sampling and analysis plan (Chen-Northern, 1990b). Quality control samples included field and laboratory duplicate samples, cross-contamination blanks, and blind

field standards. Sample train paperwork including chain-of-custody forms and analysis request forms were shipped with natural and quality control samples to Chen-Northern's analytical laboratory in Billings, Montana.

3.2 CHANGES TO THE PROJECT SAMPLING AND ANALYSIS PLAN

Only one change to the project sampling and analysis plan (Chen-Northern, 1990b) resulted from completion of the surface water sampling work task. Sampling station DF-6 was not sampled or gaged as planned because no water was flowing at this site during the low flow conditions present during the October, 1990 sampling run.

Several previously undesignated gaging stations identified in the project sampling and analysis plan were assigned station numbers during the October, 1990 sampling/gaging event. These stations are shown on Figure 3-1 and included the following:

- ◆ Station DF-6A is a gaging site established during the synoptic flow measurement event along the base of the Block P dump. The station is located on the main stem of Galena Creek.
- ◆ Station DF-5A is a gaging site located approximately 75 feet upstream of station DF-5 along the base of the Block P dump.
- ◆ Station DF-46 is a newly designated sampling and gaging station located downstream of station DF-4 and above Silver Creek (station DF-2).
- ◆ Station DF-48 is a gaging site only and is located at the Barker townsite, upstream of big Bend Creek.
- ◆ Station DF-47 is a newly designated gaging and sampling site located at the culvert below Barker.

3.3 PRESENTATION OF DATA AND RESULTS

Stream discharge and water quality data resulting from the October, 1990 sampling event are presented in Appendix A. A discussion of these data is presented in this section.

3.3.1 Flow Data

Flow data obtained during this PA are discussed in this section. Existing DNRC (1977) data are also summarized and compared to data collected during the PA.

3.3.1.1 Preliminary Assessment Data

The synoptic flow measurement episode completed during October, 1990 occurred in flow conditions which were slightly lower than the five-year average for October measurements completed by the DNRC (1977). Figure 3-2 illustrates flow relationships between the various sites gaged in Galena Creek during the synoptic flow measurement run completed during October, 1990. Field personnel subjectively rated flow measurements made during the PA as ranging from poor to good. Poor measurements resulted where the stream gradient is steep and where boulders created uneven flow in the stream.

Examination of Figure 3-2 indicates flow in Galena Creek is relatively consistent from above the Block P Mine at station DF-7 to below the mine dump at station DF-4. The slight variation in the discharge rate within this reach of the stream may actually be a function of the inaccuracy of the gaging during baseflow conditions in this high energy reach of stream. A measurable increase in flow in Galena Creek (approximately 25%) occurs in the stream reach below the Block P Mine dump bracketed by stations DF-4 and DF-46 (Figure 3-2). No surface water inputs to Galena Creek were identified in this reach of the stream. Due to this observation, we suspect the increased flow in this portion of the stream is attributable to groundwater inflow.

Galena Creek continued to gain flow from gaging station DF-46 to station DF-48 (Figure 3-2). Silver Creek enters Galena Creek within this stream reach but the magnitude of flow

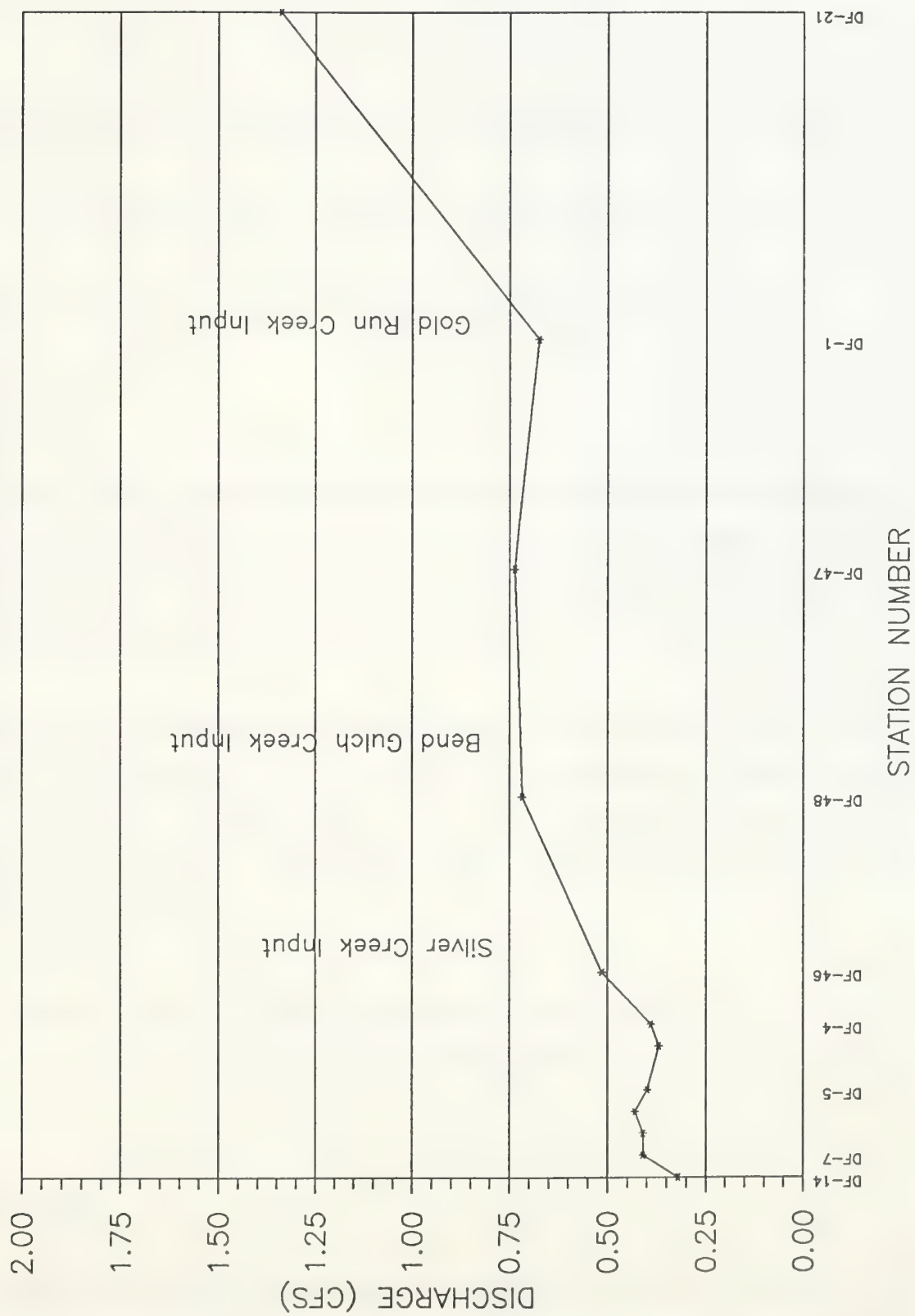
contribution from Silver Creek (0.03 cfs) does not explain the flow increase in Galena Creek of approximately 0.2 cfs. A few discharging mine adits are present in areas adjacent to Galena Creek in this stream reach. However, the combined surface input from these sources does not account for the measured flow increase in the mainstem stream. It is probable that a sizable component of the flow increase in this reach of Galena Creek is attributable to groundwater inflow.

Flow in Galena Creek was relatively constant from near the Barker townsite at station DF-48 to above the Block P mill tailings at station DF-1 (Figure 3-2). Bend Gulch Creek enters Galena Creek within this stream reach. Bend Gulch Creek contained minimal flow at the time the seepage run was completed and appeared to have little impact on the total flow in Galena Creek.

An increase in flow (about 0.7 cfs) was measured in the reach of Galena Creek from above to below the Block P mill tailings. This stream reach is bracketed by gaging stations DF-1 and DF-21 (Figure 3-2). Gold Run Creek enters the main stream in this reach. Gold Run Creek was not gaged during the seepage run. As such, it is unknown if the contribution from this tributary accounts for the entire increase in flow measured in Galena Creek between stations DF-1 and DF-21.

Flow in the Dry Fork of Belt Creek above Smoke in the Hole Creek (Station DF-40, Figure 3-1) was approximately 50% higher than the combined flows of Galena Creek (Station DF-21) and Dry Fork of Belt Creek (Station DF-22) at their confluence (Appendix A). Although several small tributaries enter the Dry Fork of Belt Creek in this reach, it is probable that the stream gains a sizeable component of flow from groundwater input.

FIGURE 3-2. SPATIAL DISTRIBUTION OF
DISCHARGE IN GALENA CREEK; OCTOBER, 1990
GALENA CREEK PRELIMINARY ASSESSMENT



Point source flow contributions to Galena Creek gaged during October, 1990, were relatively insignificant with respect to the total discharge gaged on Galena Creek. Point sources gaged for the purposes of this study are shown on Figure 3-1 and include the following stations:

- ◆ Station DF-45 -- Discharge from the Queen adit (estimated 0.002 cfs),
- ◆ Station DF-2 -- Silver Creek at its mouth (0.026 cfs), and,
- ◆ Station DF-3 -- the Danny T mine seep (estimated 0.004 cfs).

3.3.1.2 DNRC Data

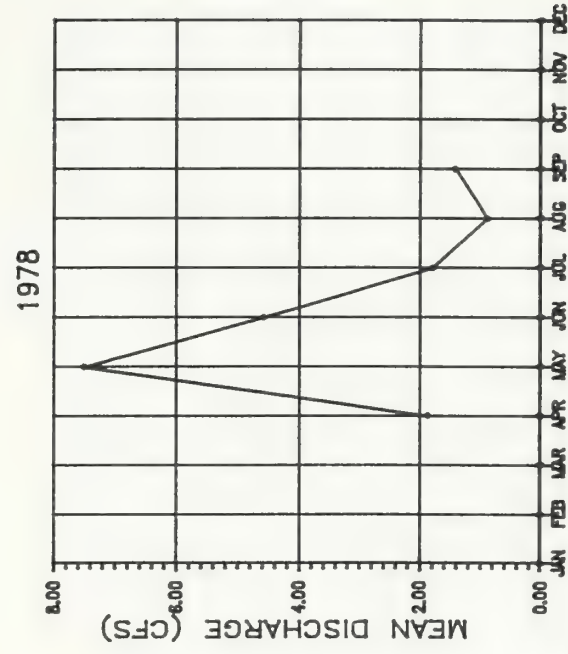
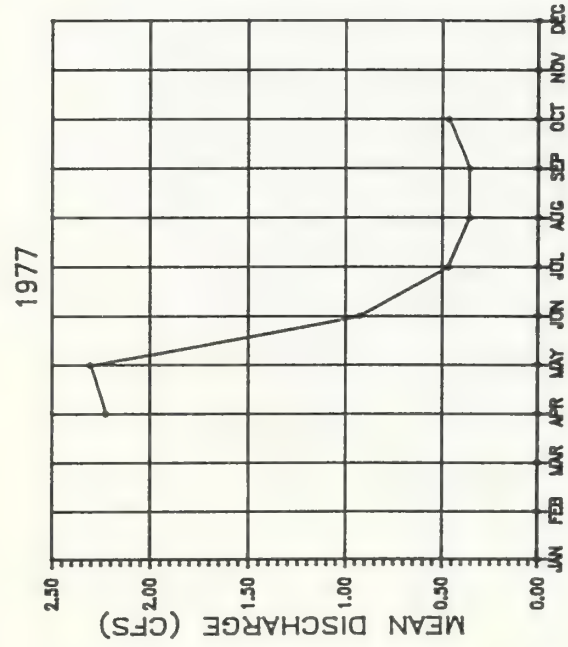
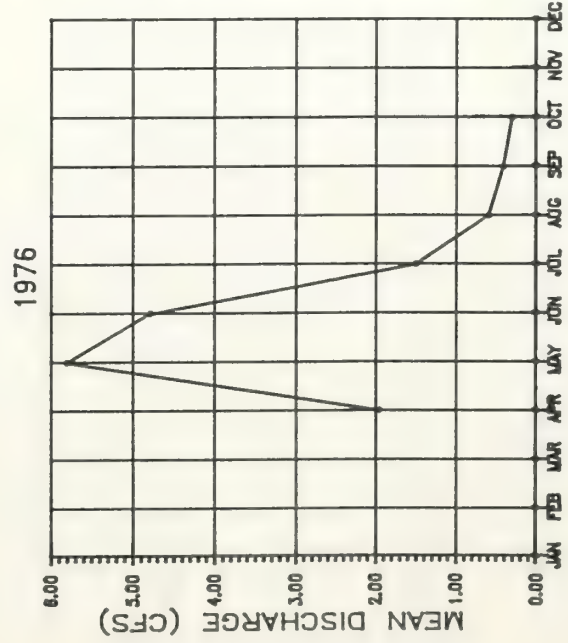
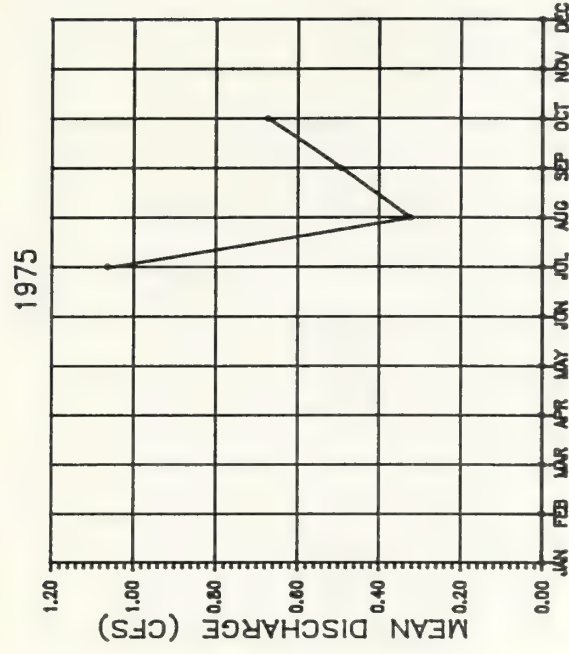
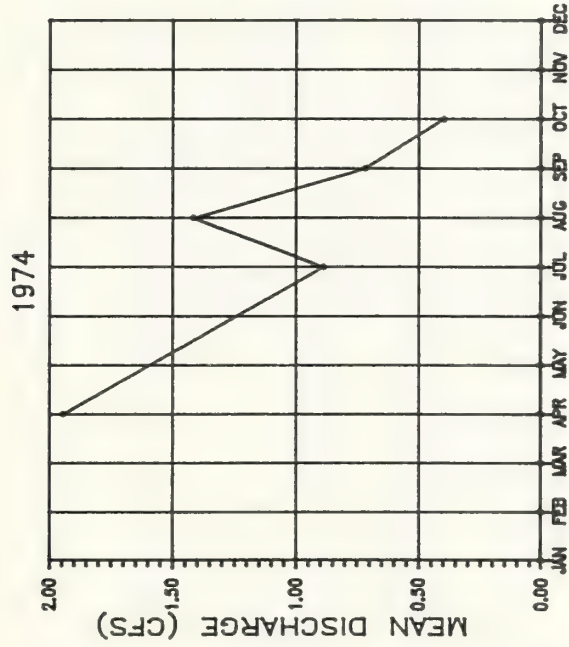
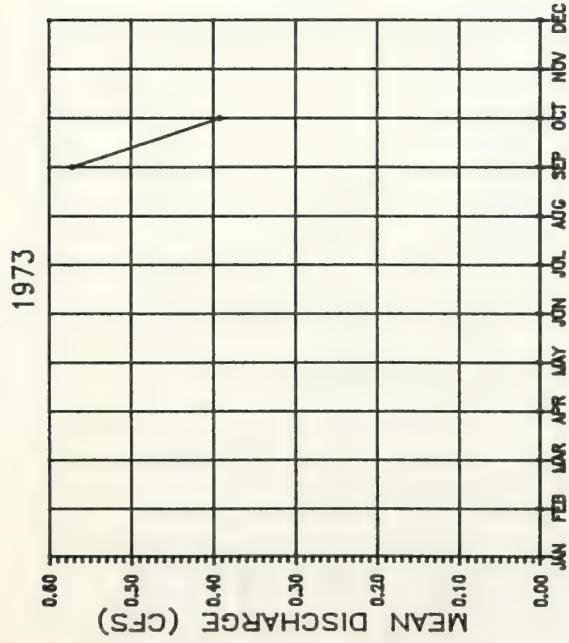
Flow data were obtained during sampling events completed by the Montana Water Quality Bureau in support of a feasibility study analysis by the DNRC (1977). These data were obtained from 1973 to 1977 and included seasonal continuous flow records, instantaneous flow measurements, and estimates of flow.

The highest recorded flow on Galena Creek near Barker was 24.3 cfs in April, 1974. Figures 3-3 through 3-7 are hydrographs developed with DNRC flow data for Galena Creek at the upper weir (DF-7), Galena Creek at the lower weir (DF-1), discharge from an adit at the Block P Mine (DF-6), discharge from Silver Creek (DF-2), and discharge from the Danny T Mine adit (DF-3).

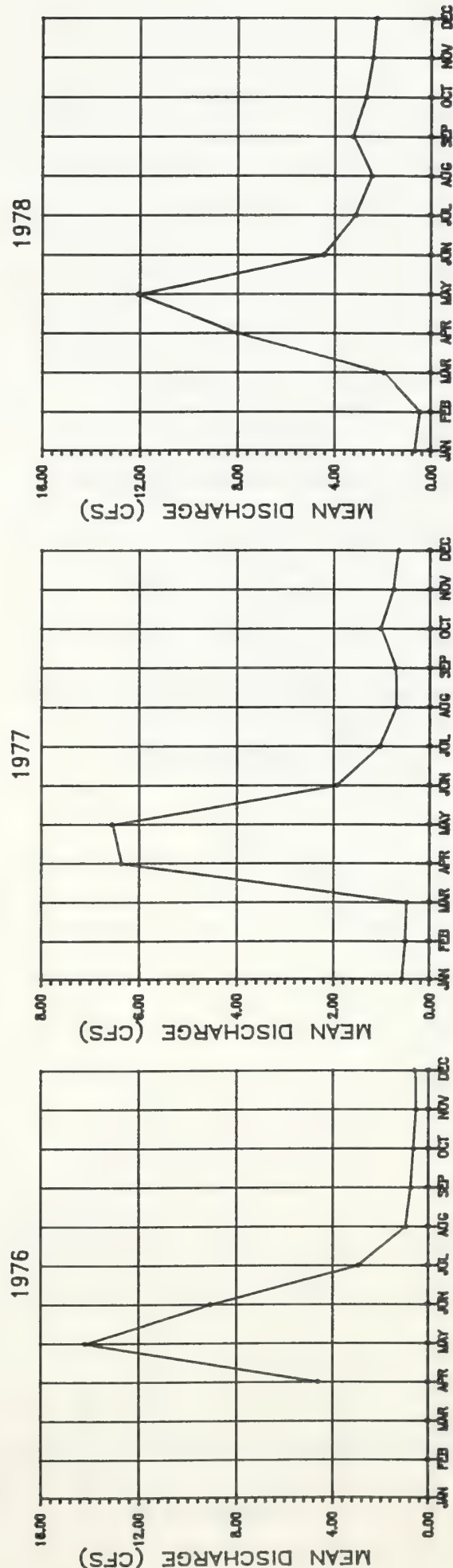
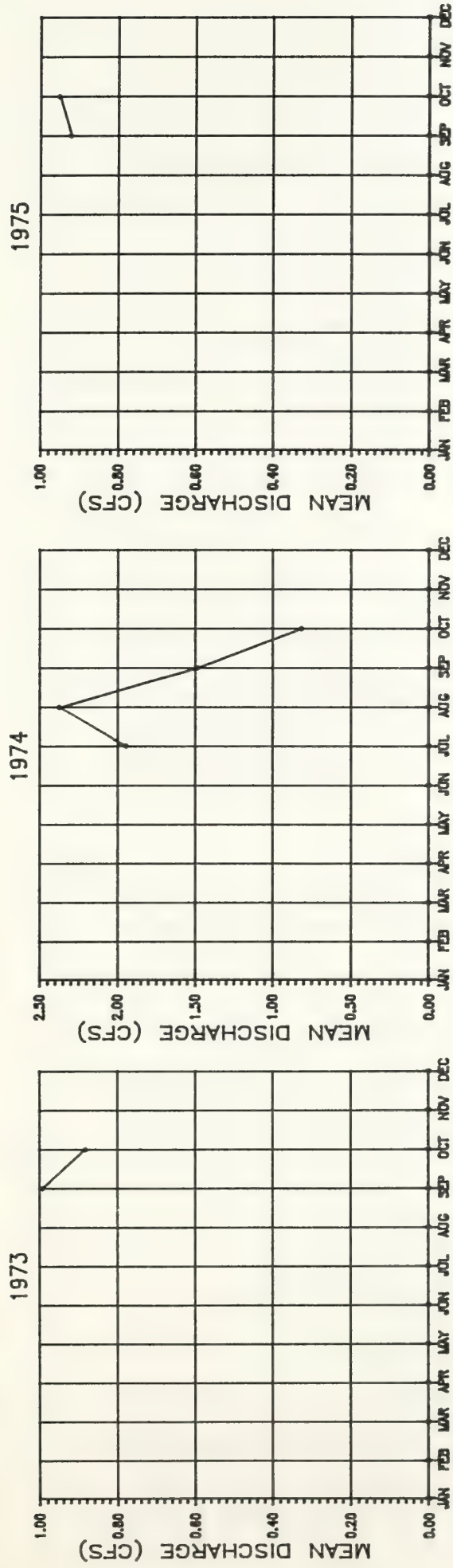
The hydrographs indicate the highest flows at the various sites occur during the April to June time period. Flow from the adit at the Block P Mine (DF-6) usually ceases by late summer to early fall.

3.3.2 Water Quality Data

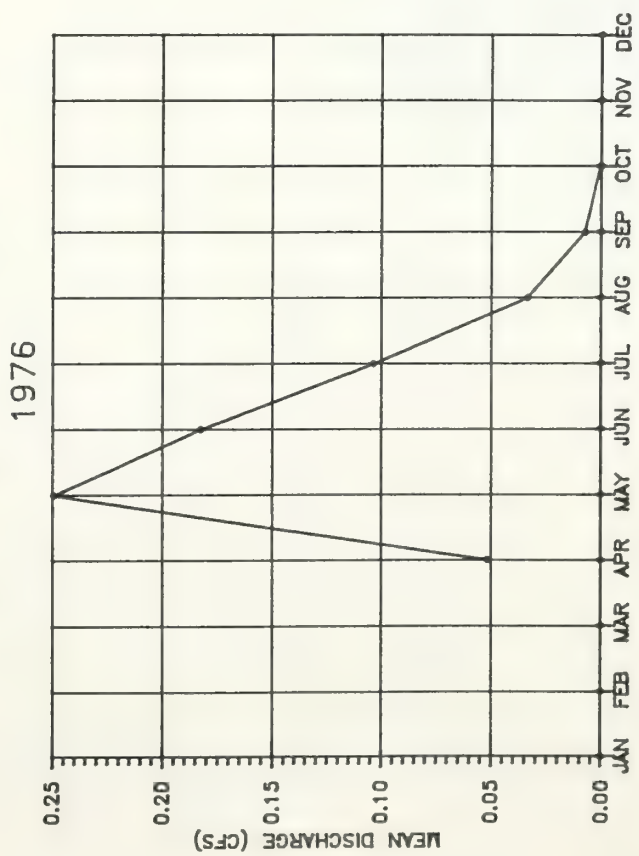
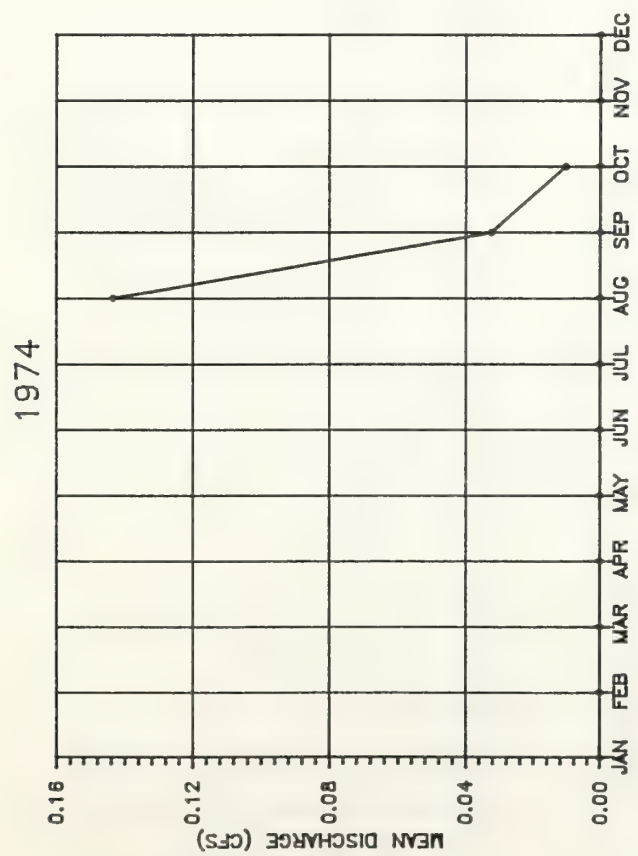
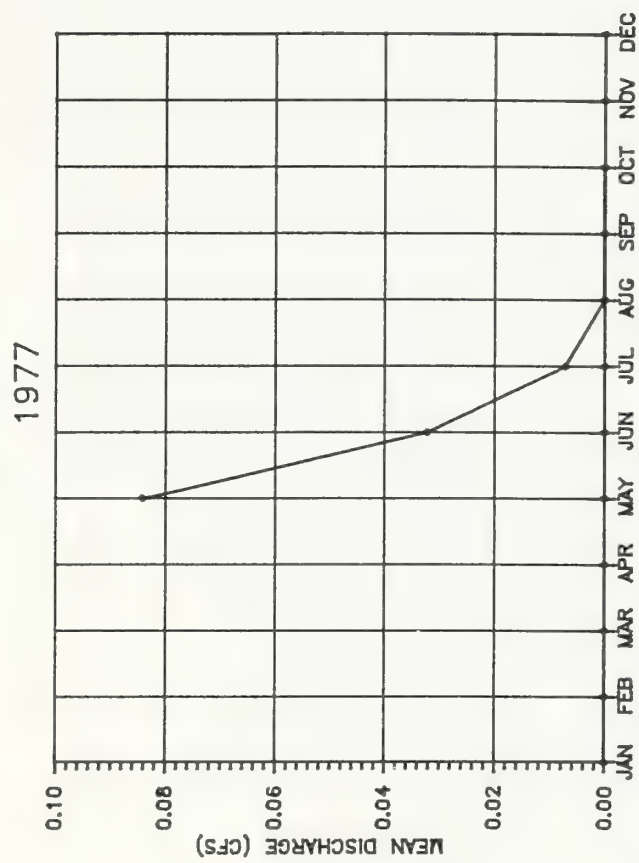
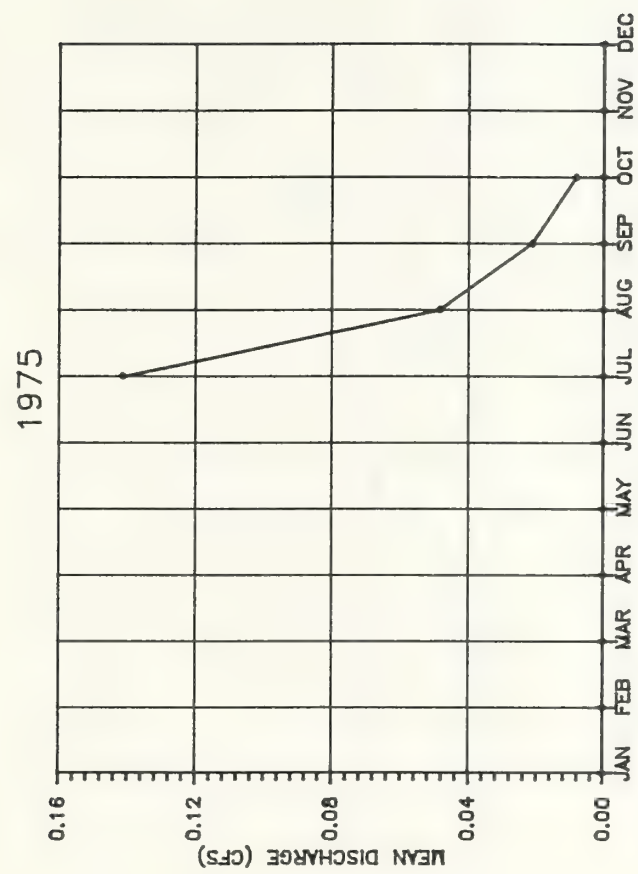
In this section, surface water quality data collected during this PA are presented and interpretations are made. In addition, existing DNRC data (DNRC, 1977) have been



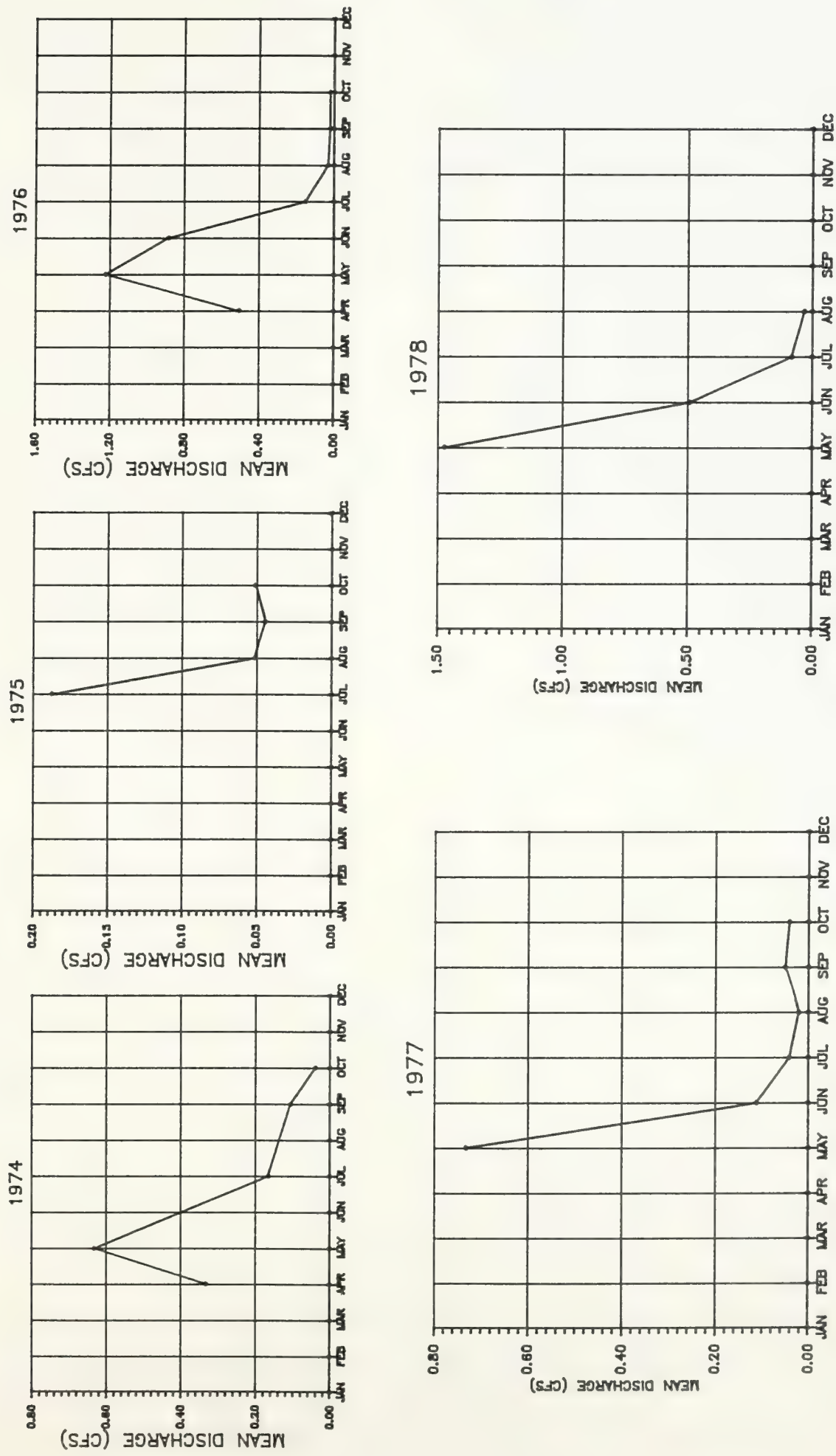
Hydrographs of Flow at Station DF-7 on Galena Creek (1973-1978)
FIGURE 3-3



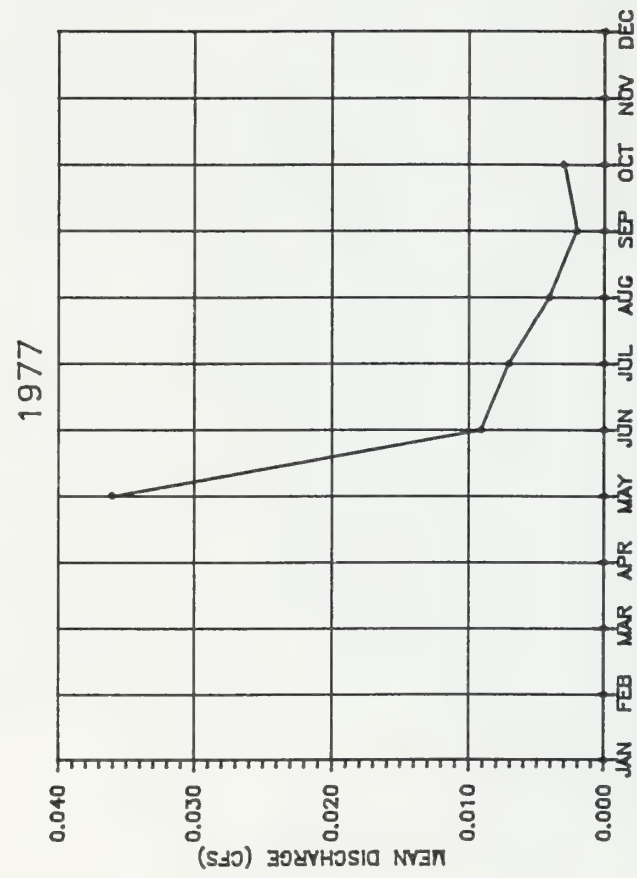
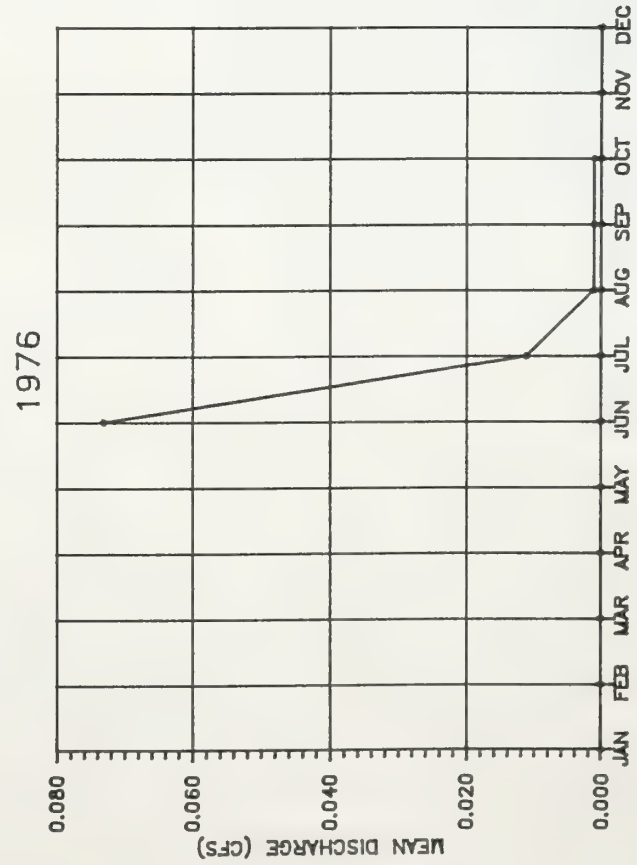
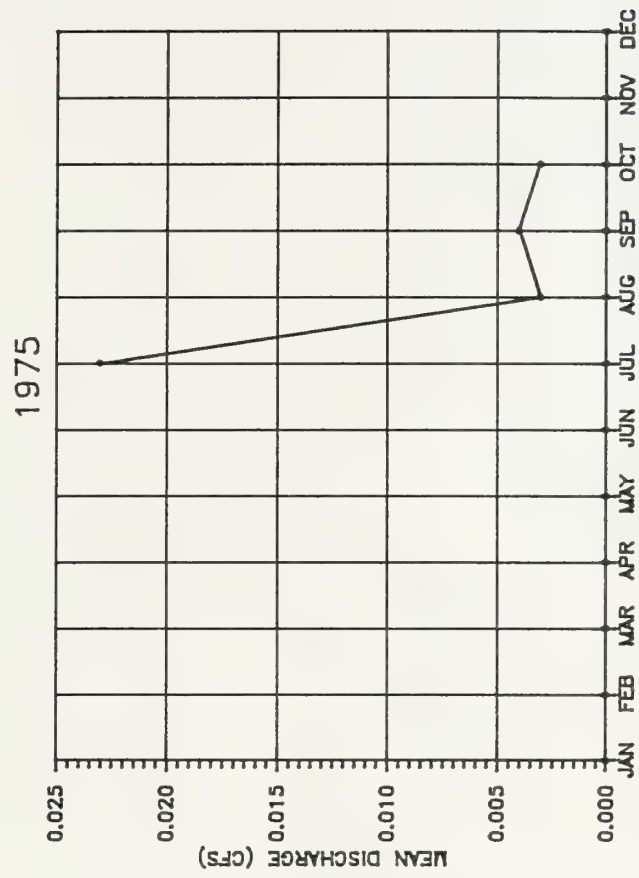
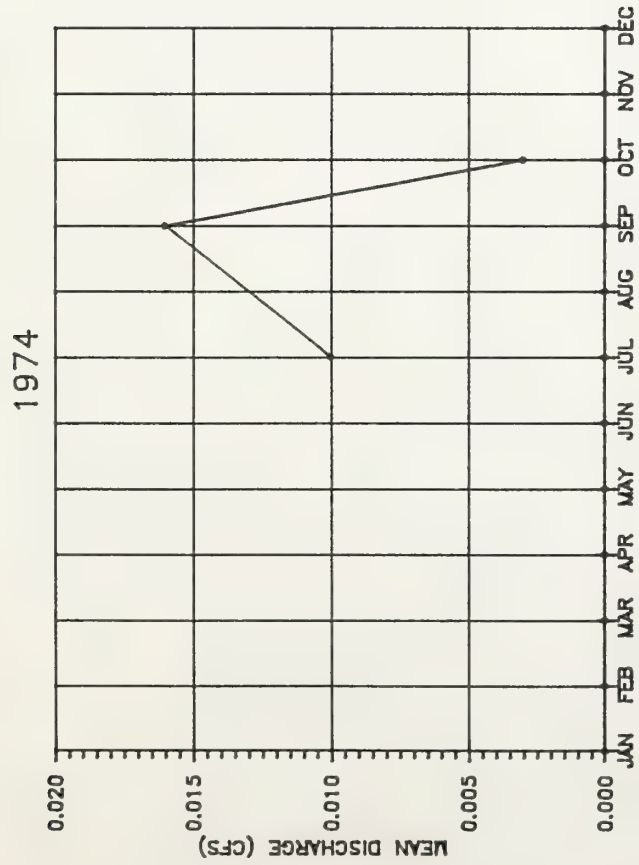
Hydrographs of Flow at Station DF-1 on Galena Creek (1973-1978)
FIGURE 3-4



Hydrographs of Flow at the Block P Adit Discharge (Station DF-6) from 1974-1977
FIGURE 3-5



Hydrographs of Flow at Station DF-2 on Silver Creek (1974-1978)
FIGURE 3-6



Hydrographs of Flow at the Liberty Mine Adit (Station DF-3) from 1974-1977
FIGURE 3-7

incorporated into the discussion to present a more complete analysis of the chemical nature of the area's surface water systems.

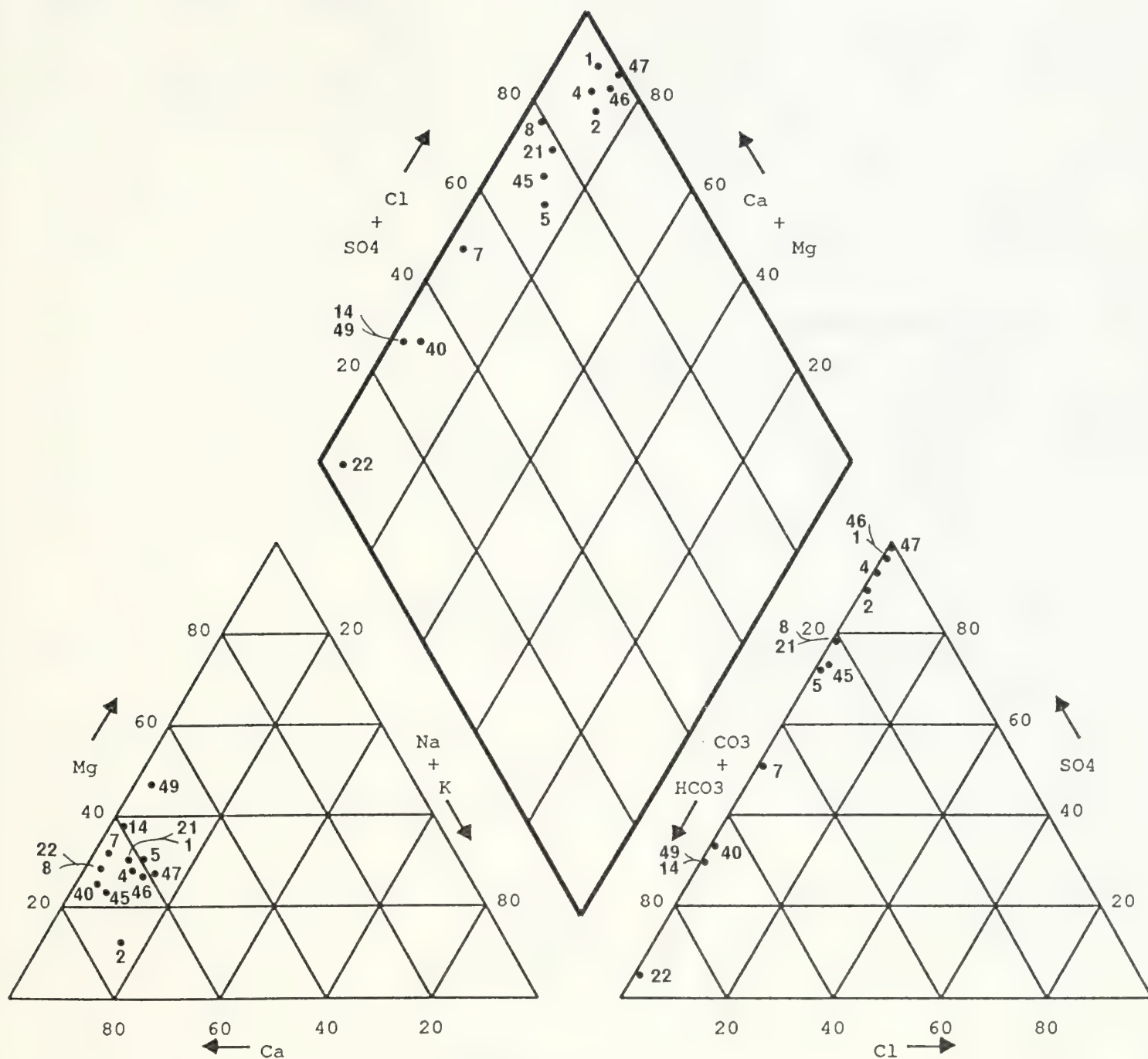
3.3.2.1 Common Ions

Figure 3-8 is a trilinear diagram of the various surface water sites sampled during the October, 1990 sampling event. Figure 3-9 illustrates stiff diagrams presented spatially for these same data sets. Examination of these figures indicates that surface water stations DF-14, DF-22, and DF-40 group together as a calcium bicarbonate type water. This water type is unique with respect to other stations sampled. Other sampled stations (both main stem stations and point source inputs) exhibited a calcium sulfate type water.

Station DF-14 is located on Green Creek above the Block P Mine area (Figure 3-1). The type of water in this drainage likely represents that which is relatively unimpacted by mining wastes. Stations DF-22 and DF-40 are located on the Dry Fork of Belt Creek above and below its confluence with Galena Creek respectively (Figure 3-1). It is apparent that dilution from water in the Dry Fork of Belt Creek above Galena Creek (as measured at station DF-22) and other chemical changes occurring in the Dry Fork serve to minimize the impact of Galena Creek on the Dry Fork with respect to the distribution and abundance of major ions .

Figures 3-8 and 3-9 also illustrate that the water type in Galena Creek gradually changes from a calcium bicarbonate to a calcium sulfate type with distance downstream. The magnitude of the calcium and sulfate concentrations in Galena Creek is relatively constant from below the Block P Mine dump at station DF-4 to the mouth of the stream at DF-21 (Figure 3-9).

Point source inputs to Galena Creek sampled during the October, 1990 sampling event (stations DF-49, DF-45, DF-2, and DF-3, Figure 3-1) exhibited a calcium sulfate type water with the exception of the Carter Mine adit (station DF-49). Water issuing from the Carter Mine is a calcium bicarbonate type which is similar to that in nearby Green Creek (station DF-14, Figure 3-9). Seepage from the Danny T Mine (station DF-3) exhibited a relatively



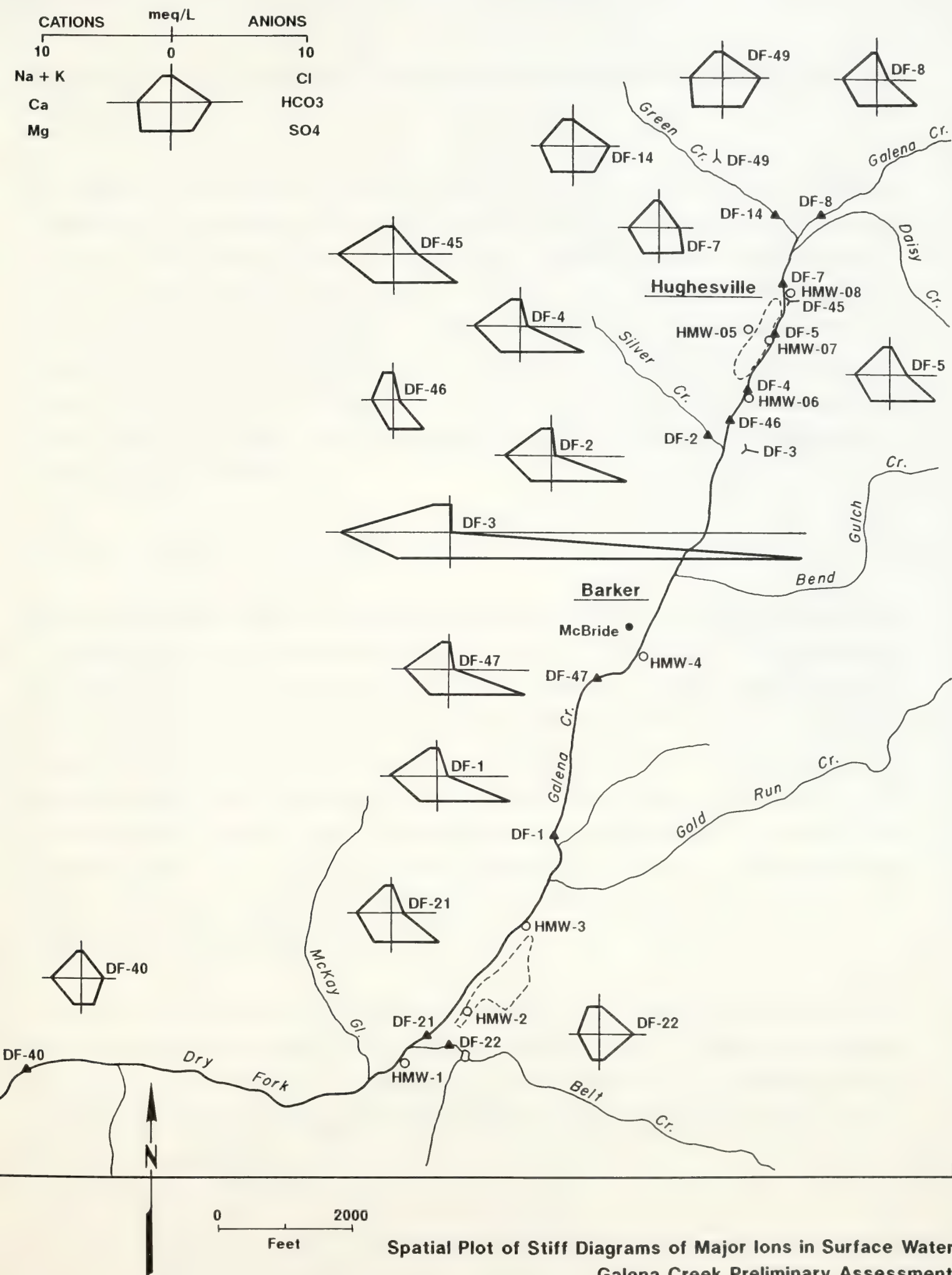
Cations

% meq/l

Anions

Trilinear Diagram of Major Ions in Surface Water
Galena Creek Preliminary Assessment

FIGURE 3-8



**Spatial Plot of Stiff Diagrams of Major Ions in Surface Water
Galena Creek Preliminary Assessment**

large component of both calcium and sulfate ions as compared to other sites sampled (Figure 3-9).

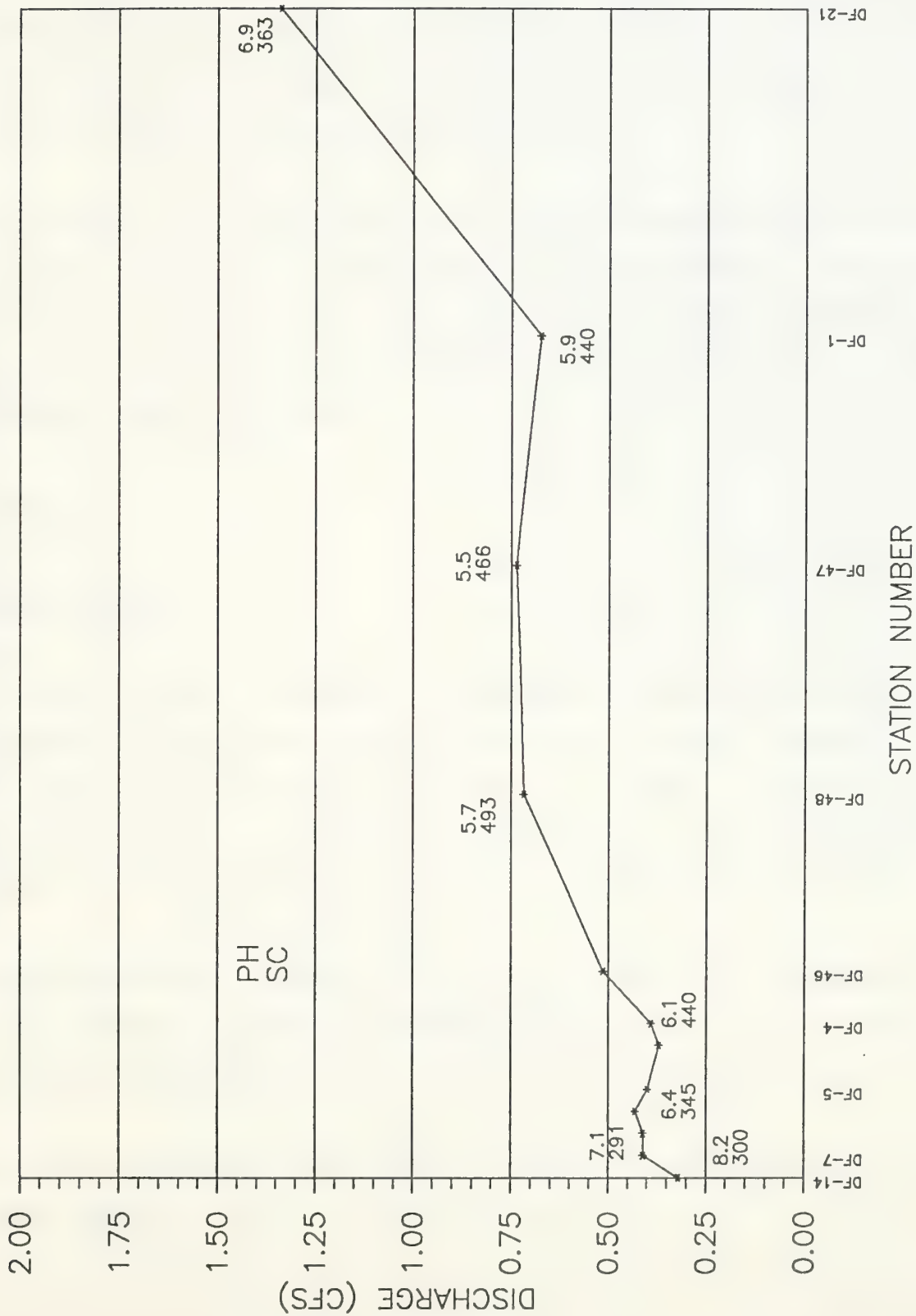
The foregoing indicates that surface water in the study area in reaches relatively unaffected by mine wastes is a calcium bicarbonate type. This type of water is present in Green Creek. Where inputs of acidic water to the stream occur, Galena Creek is characterized by a calcium sulfate type water. Based on this relationship, it appears that Galena Creek may be impacted by mine wastes in the reach above its confluence with Green Creek and, more dramatically, in the vicinity of the Block P Mine and dump. Because calcium bicarbonate rich flow in the Dry Fork of Belt Creek is substantially greater than that in Galena Creek, the impacts to the Dry Fork below its confluence with Galena Creek are minimized.

3.3.2.2 Specific Conductance and pH

Figure 3-10 shows specific conductivity (SC) and pH values for surface water stations sampled along Galena Creek during this investigation. The plot shows that pH values in the stream decrease markedly from above the Block P Mine dump at station DF-14 on Green Creek (8.2 s.u.) to below the mine dump at station DF-46 (5.7 s.u.). pH values remain relatively stable (about 5.5 s.u.) in the reach of stream from DF-46 to the station above the Block P Mill tailings (DF-1). A full standard unit increase in pH was measured in Galena Creek from the station above the Block P Mill tailings (DF-1) to below the deposit at station DF-21 (Figure 3-10). The pH at station DF-40 (7.9 s.u.) in the Dry Fork of Belt Creek was a standard unit higher than that measured at the mouth of Galena Creek at station DF-21 (Appendix A).

The occurrence of the measured increase in stream pH at the lower end of Galena Creek and into the Dry Fork of Belt Creek generally coincides with the location of Cambrian limestone units which subcrop to the stream. Such carbonaceous materials probably contribute substantial buffering, thereby influencing stream pH, particularly during low flow and baseflow periods.

FIGURE 3-10. DISCHARGE, SPECIFIC CONDUCTANCE and
 pH VALUES IN GALENA CREEK; OCTOBER, 1990
 GALENA CREEK PRELIMINARY ASSESSMENT



Specific conductance measured at main stem stations on Galena Creek ranged from 291 to 493 $\mu\text{mhos/cm}$ at 25° C. The trend in SC values of sampled sites is inverse that of pH. Relatively low conductivity surface water (300 to 350 $\mu\text{mhos/cm}$) was measured at stations located above the Block P Mine dump and near the mouth of Galena Creek. Relatively high SC water (450 to 490 $\mu\text{mhos/cm}$) was measured at stations located adjacent to and below the Block P Mine dump (Figure 3-10).

A relatively low pH value (2.9 s.u.) and high SC value (2,176 $\mu\text{mhos/cm}$ at 25° C) were measured in a sample collected from a seep emanating from the Danny T Mine adit (Figure 3-1). The magnitude of these values is consistent with the presence of relatively high metals and major ion concentrations measured in this water sample. This relationship is discussed later in this section.

3.3.2.3 Metals

Preliminary Assessment Data

Figure 3-11 summarizes metals concentrations measured in surface water samples collected during the PA. Figures 3-12 through 3-17 are plots of cadmium, copper, zinc, iron, lead, and manganese concentrations, respectively, in samples collected during October, 1990 at Galena Creek sampling stations. pH values are also included on the plots for comparative purposes. Examination of these figures indicates the following:

- ♦ Metals concentrations in Galena Creek increase measurably in the reach of stream adjacent to and below the Block P Mine and dump. Concentrations generally decrease downstream to the mouth of the stream.
- ♦ An inverse relationship exists between metals concentrations and pH in Galena Creek.

Flow - Cubic feet per second (cfs)

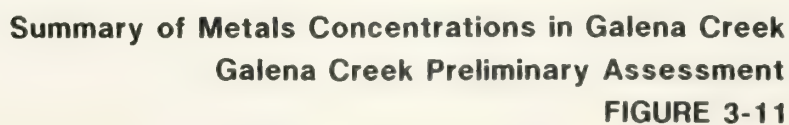


FIGURE 3-12 CADMIUM CONCN. IN GALENA CREEK; OCT., 1990

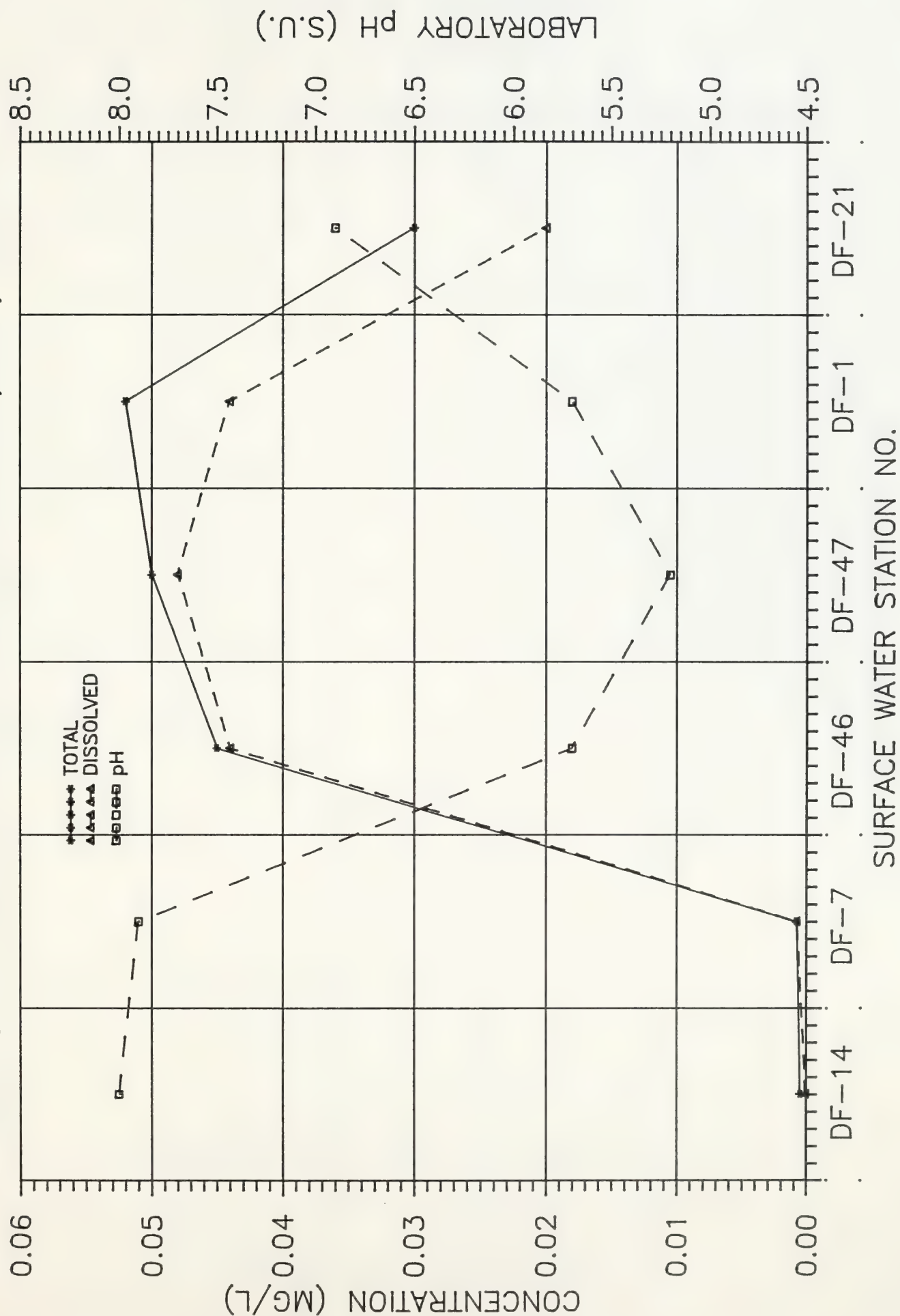


FIGURE 3-13 COPPER CONCENTRATIONS IN GALENA CR., OCT., 1990

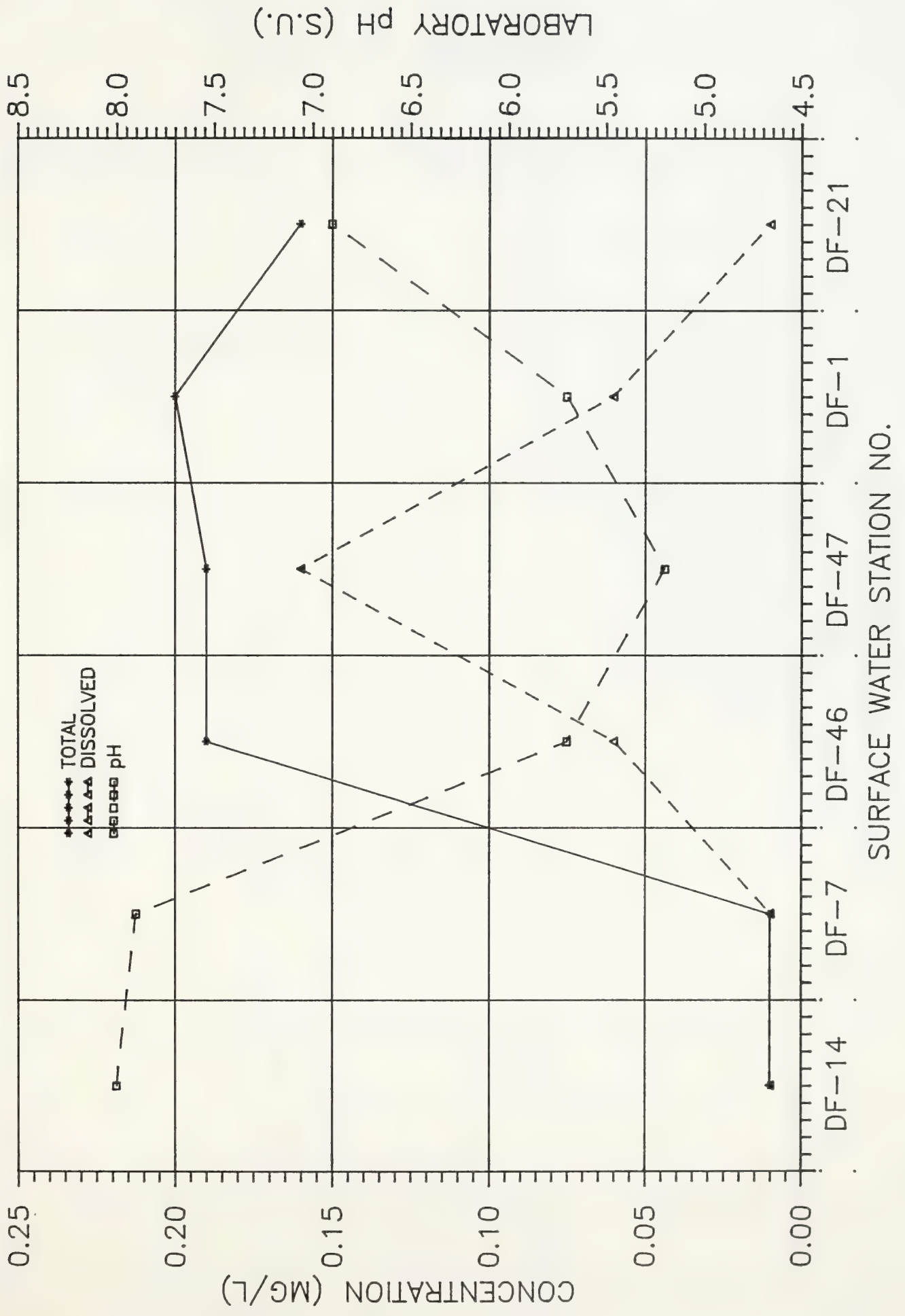


FIGURE 3-14 ZINC CONCENTRATIONS IN GALENA CR.; OCT., 1990

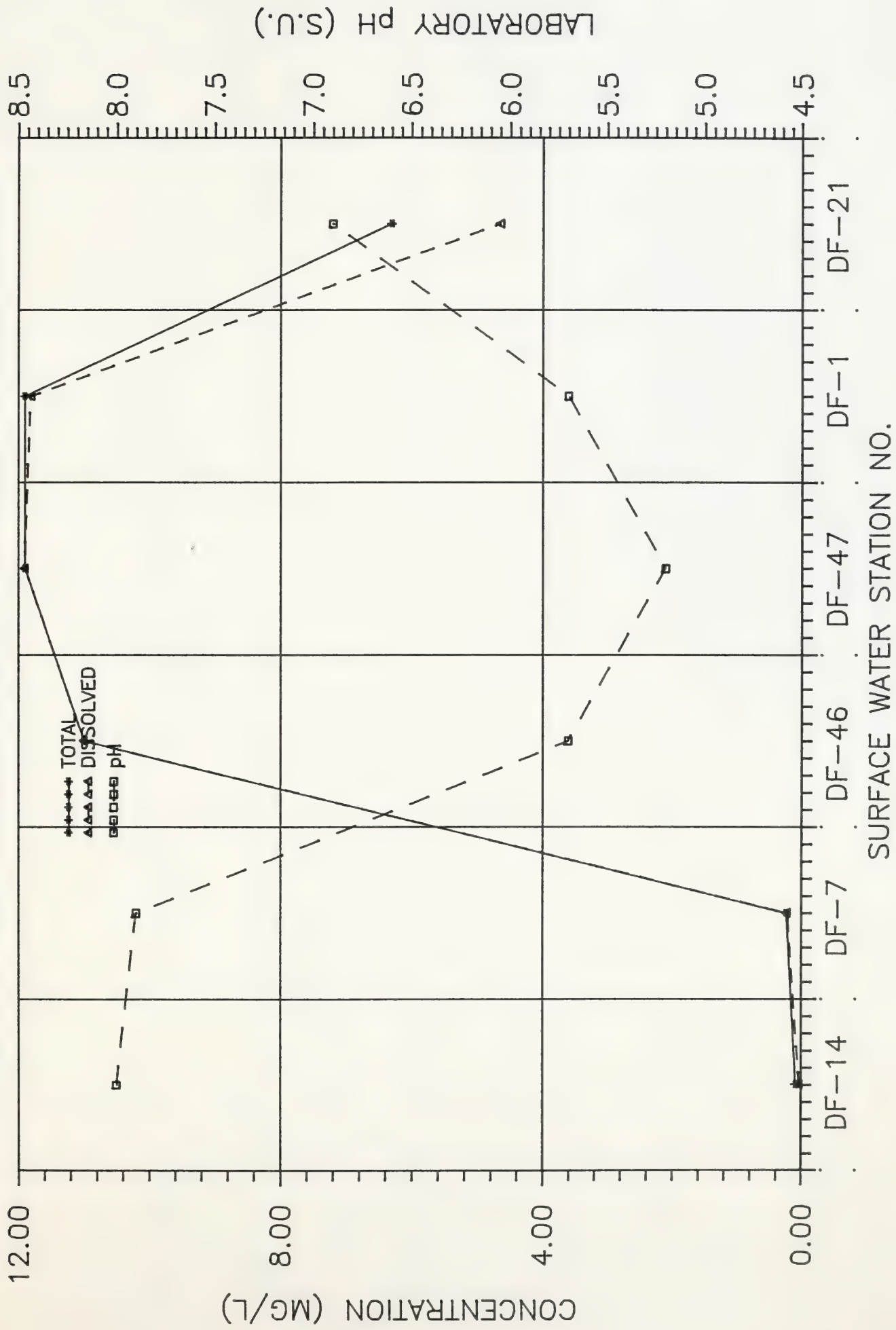


FIGURE 3-15 IRON CONCENTRATIONS IN GALENA CR.; OCT., 1990

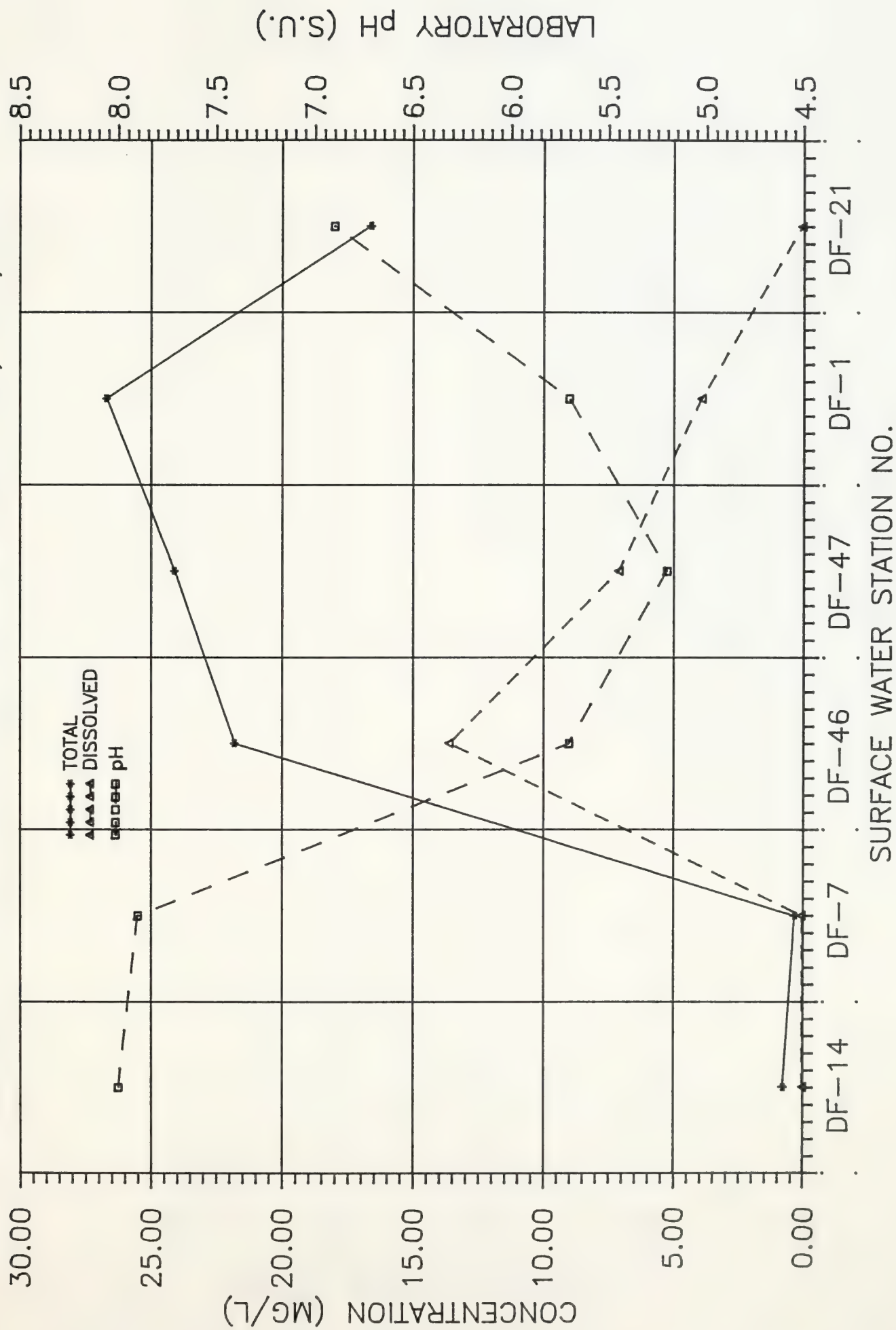


FIGURE 3-16 LEAD CONCENTRATIONS IN GALENA CR.; OCT., 1990

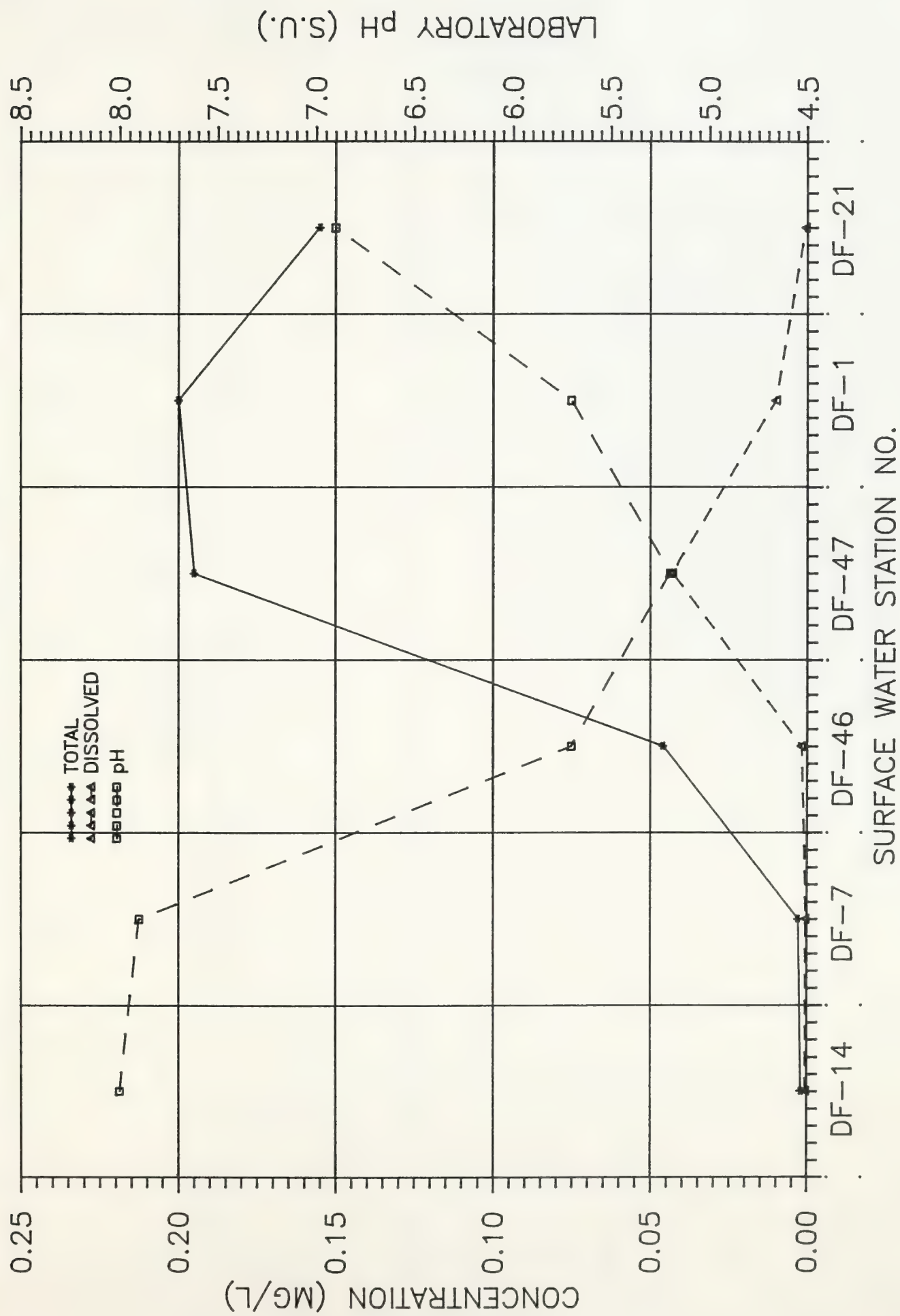
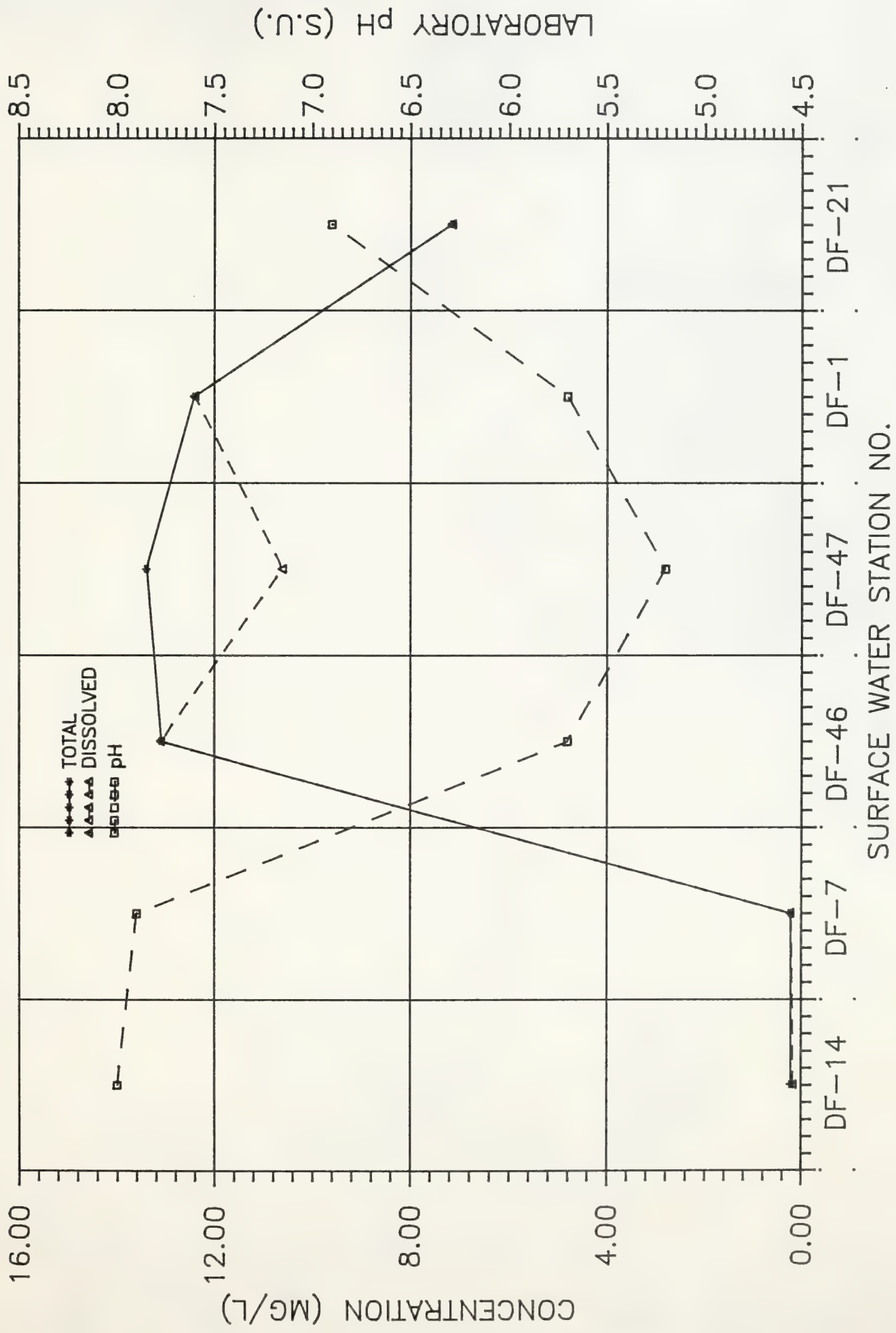


FIGURE 3-17 MANGANESE CONC. IN GALENA CR.; OCT., 1990



Total Recoverable/Dissolved Metals ($\mu\text{g/L}$)
Flow - Cubic feet per second (cfs)

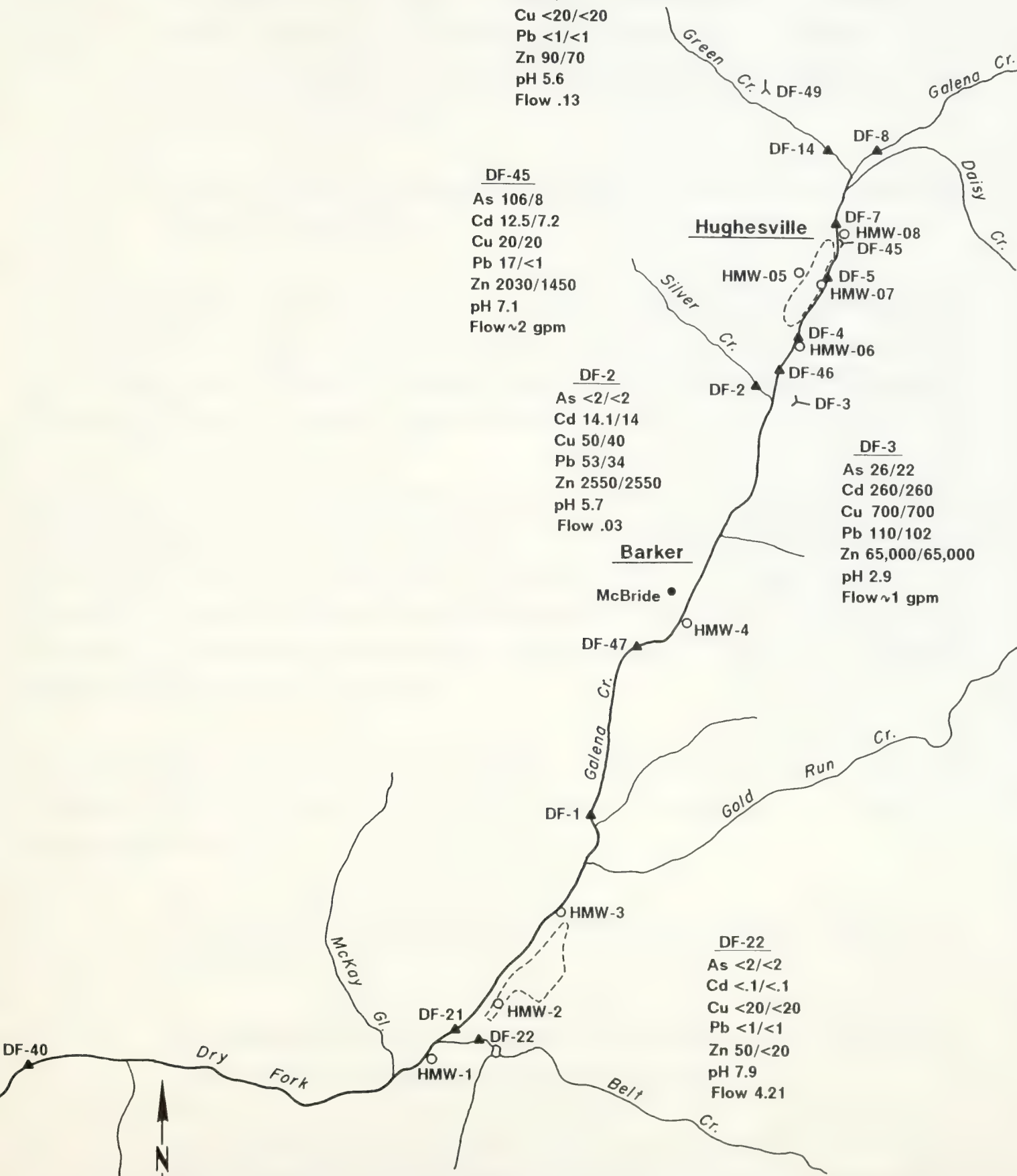
DF-49
 As 21/5
 Cd .2/<.1
 Cu <20/<20
 Pb <1/<1
 Zn 90/70
 pH 5.6
 Flow .13

DF-45
 As 106/8
 Cd 12.5/7.2
 Cu 20/20
 Pb 17/<1
 Zn 2030/1450
 pH 7.1
 Flow ~2 gpm

DF-2
 As <2/<2
 Cd 14.1/14
 Cu 50/40
 Pb 53/34
 Zn 2550/2550
 pH 5.7
 Flow .03

DF-3
 As 26/22
 Cd 260/260
 Cu 700/700
 Pb 110/102
 Zn 65,000/65,000
 pH 2.9
 Flow ~1 gpm

DF-22
 As <2/<2
 Cd <.1/<.1
 Cu <20/<20
 Pb <1/<1
 Zn 50/<20
 pH 7.9
 Flow 4.21



**Summary of Metals Concentrations
 in Point Sources to Galena Creek
 Galena Creek Preliminary Assessment
 FIGURE 3-18**

- ◆ At relatively low pH values (< 6 s.u.) almost all metals are present in the dissolved fraction. At pH values greater than about 6 s.u., certain metals (particularly copper and iron) precipitate, resulting in a greater proportion of metals in the total fraction.
- ◆ Certain metals (e.g. manganese) remain in solution at all pH conditions present in Galena Creek.

The most prominent metals in the surface water system are cadmium, lead, zinc, iron, and manganese. Copper and arsenic are present but in relatively low concentrations. Other metals analyzed in samples collected from Galena Creek exhibited concentrations that were at or near the analytical method detection limit.

Figure 3-18 summarizes selected metals concentrations in point source inputs to Galena Creek sampled during the October, 1990 sampling event. This figure indicates that metals in the point sources are relatively high compared to water in Galena Creek with the exception of the sample obtained from the Carter Mine (station DF-49). Discharge from the Danny T Mine (station DF-3) contains metals concentrations significantly higher than other water sampled in the study area.

Plots of copper, zinc, iron, lead, and manganese loading in Galena Creek during the October, 1990 sampling event are shown on Figures 3-19 through 3-23. These plots indicate the following:

- ◆ Metals loading generally increases from the headwater area of Galena Creek to its mouth.
- ◆ The largest increases in metals loading occurs in the reach of Galena Creek between the Block P Mine and the Barker townsite.
- ◆ Zinc and manganese loads are carried throughout the Galena Creek system primarily in the dissolved fraction.

FIGURE 3-19 COPPER LOADS IN GALENA CREEK; OCT., 1990

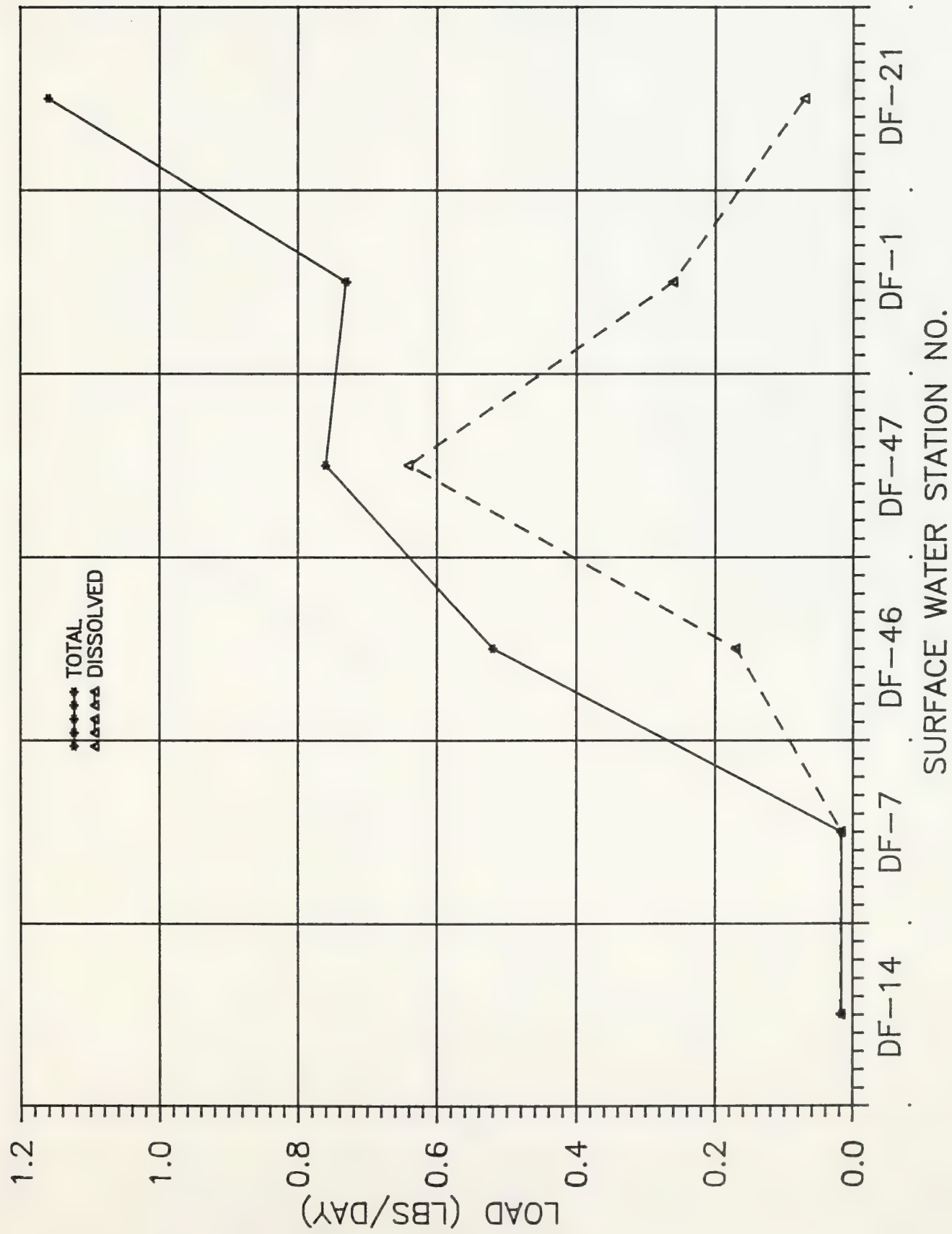


FIGURE 3-20 ZINC LOADS IN GALENA CREEK; OCT., 1990

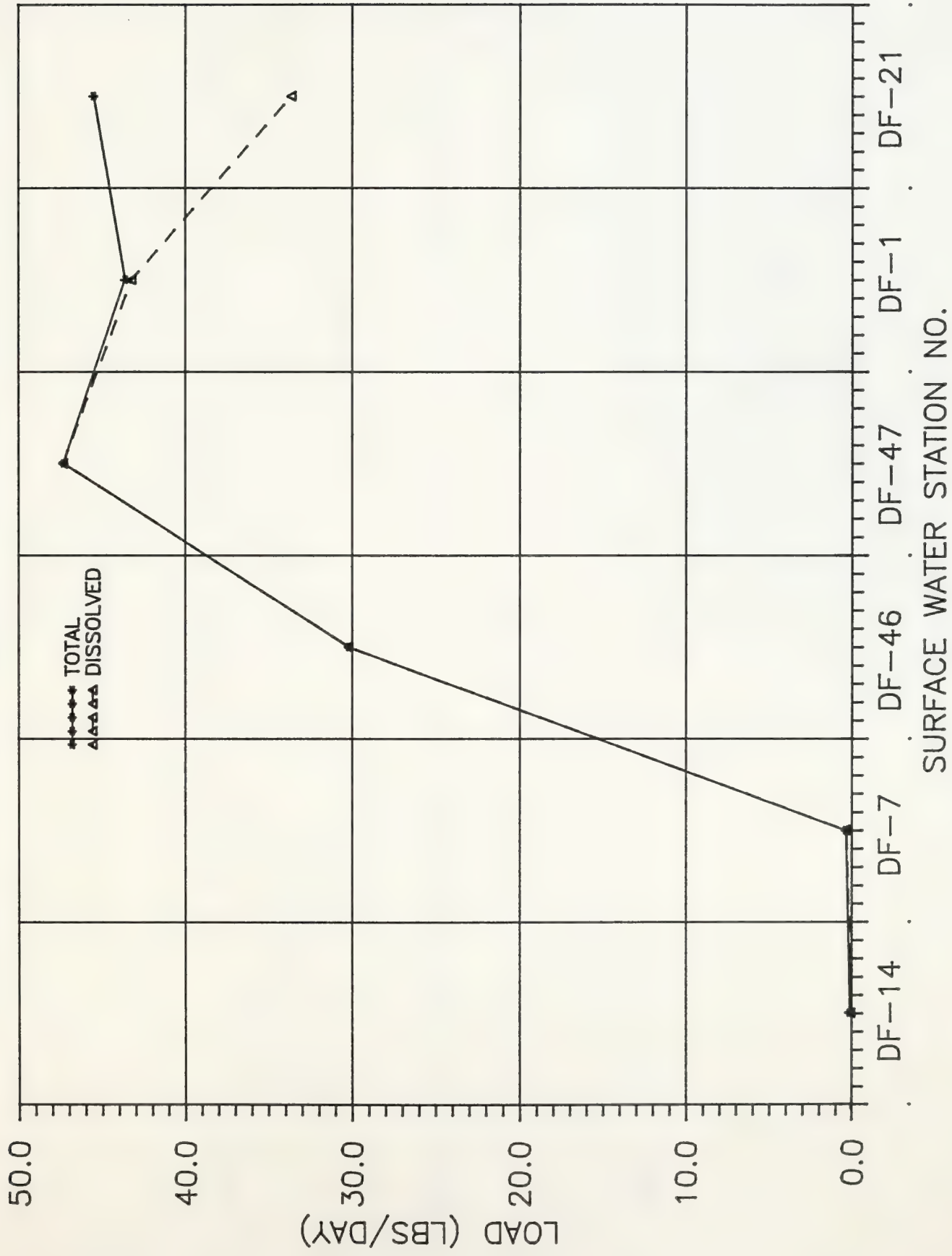


FIGURE 3-21 IRON LOADS IN GALENA CREEK; OCT., 1990

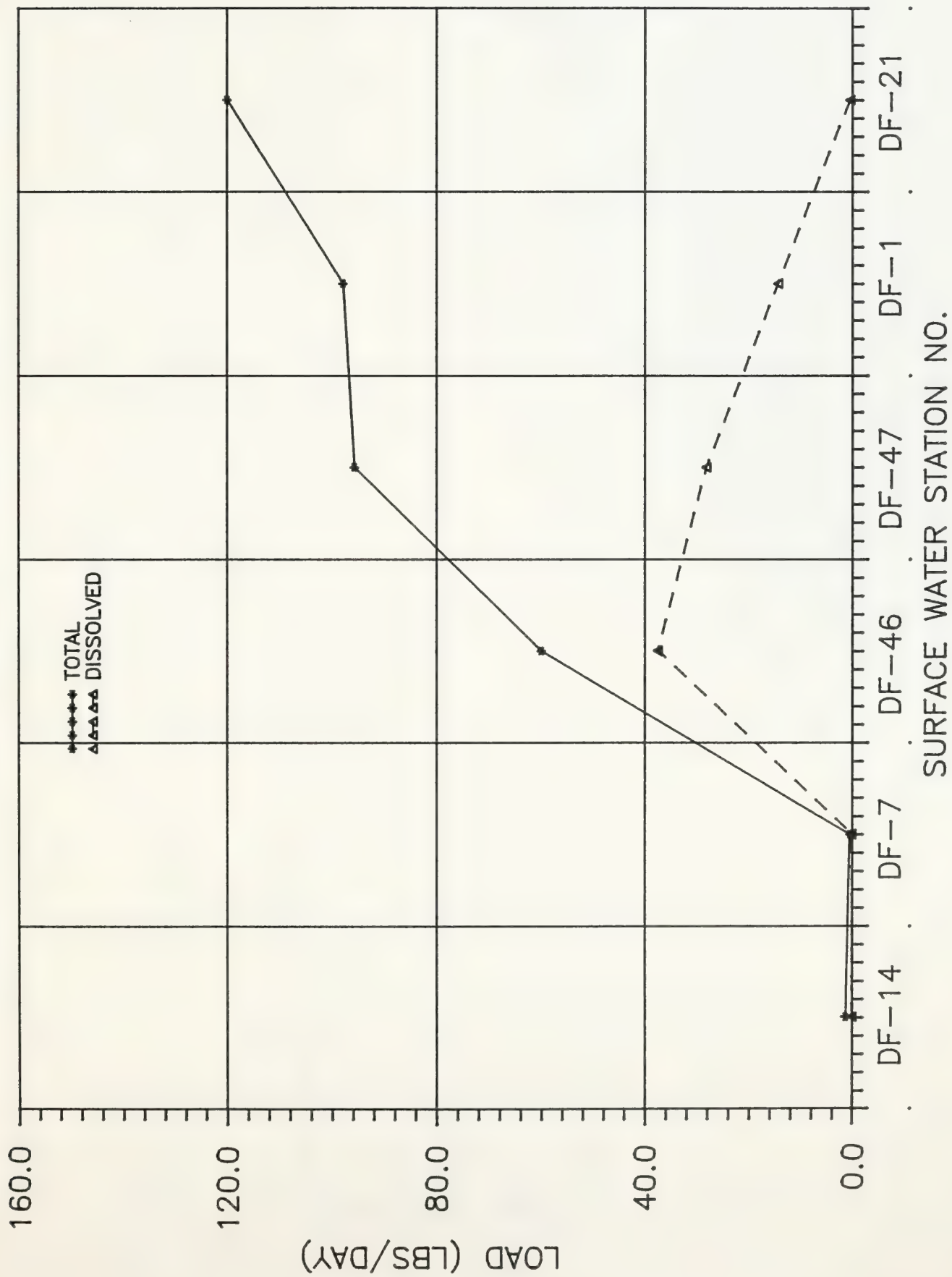


FIGURE 3-22 LEAD LOADS IN GALENA CREEK; OCT., 1990

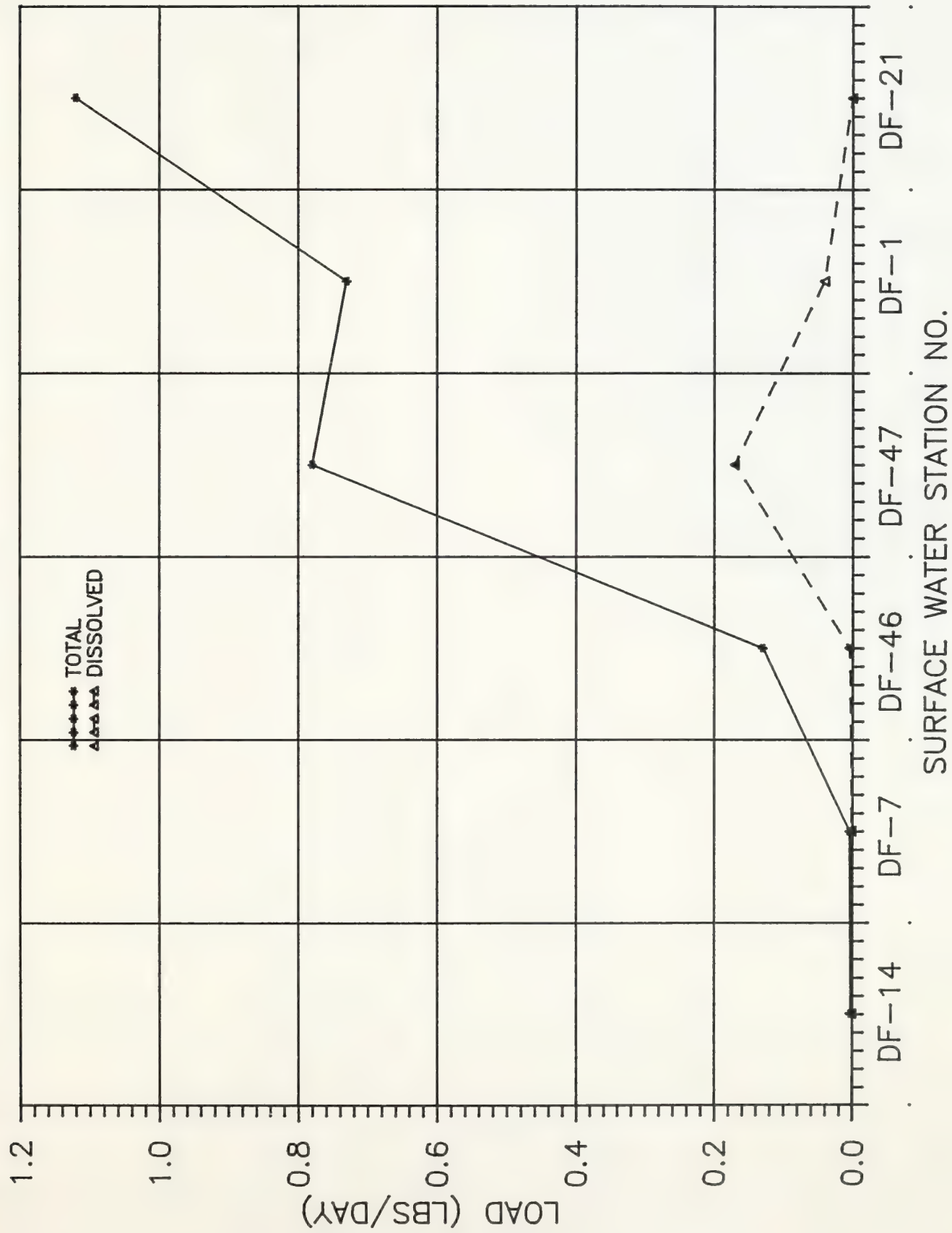
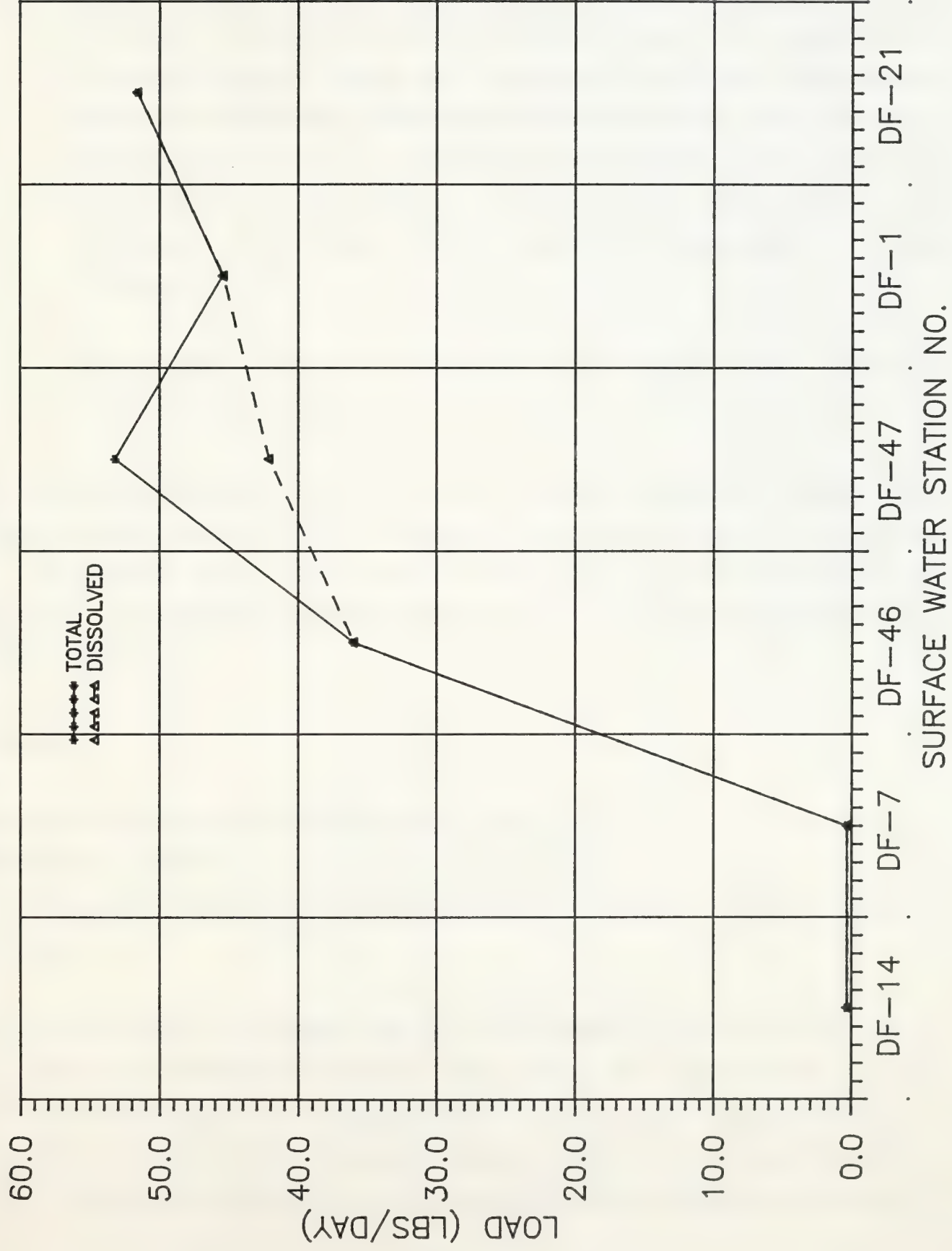


FIGURE 3-23 MANGANESE LOADS IN GALENA CR.; OCT., 1990



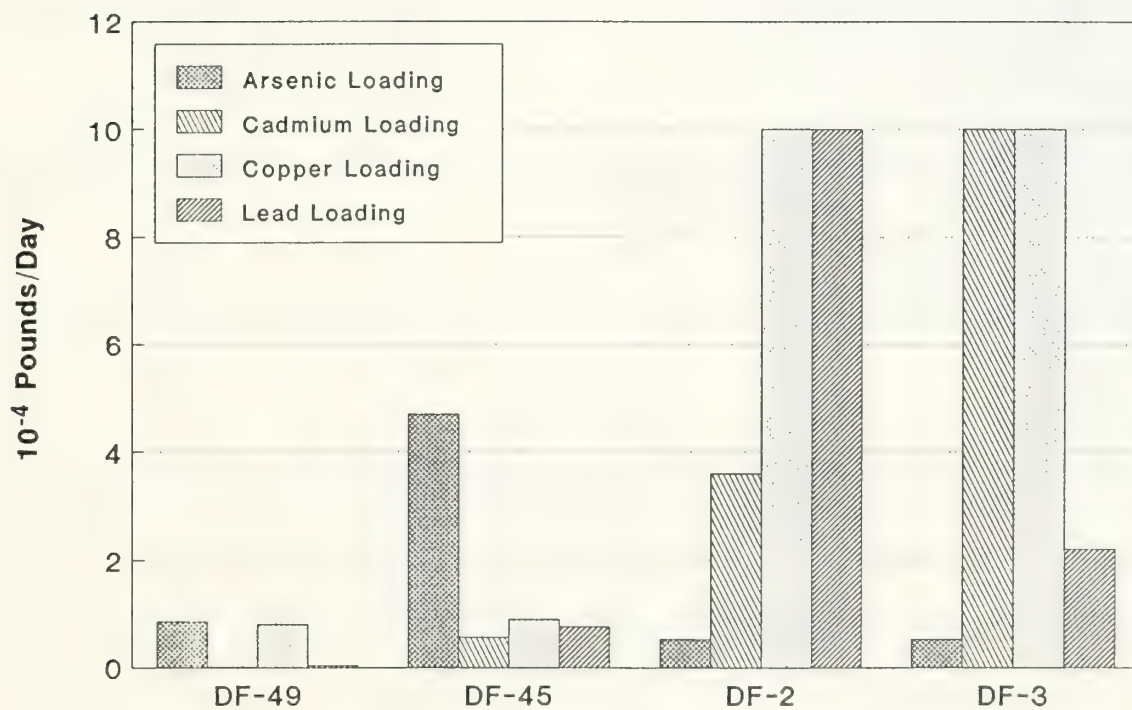
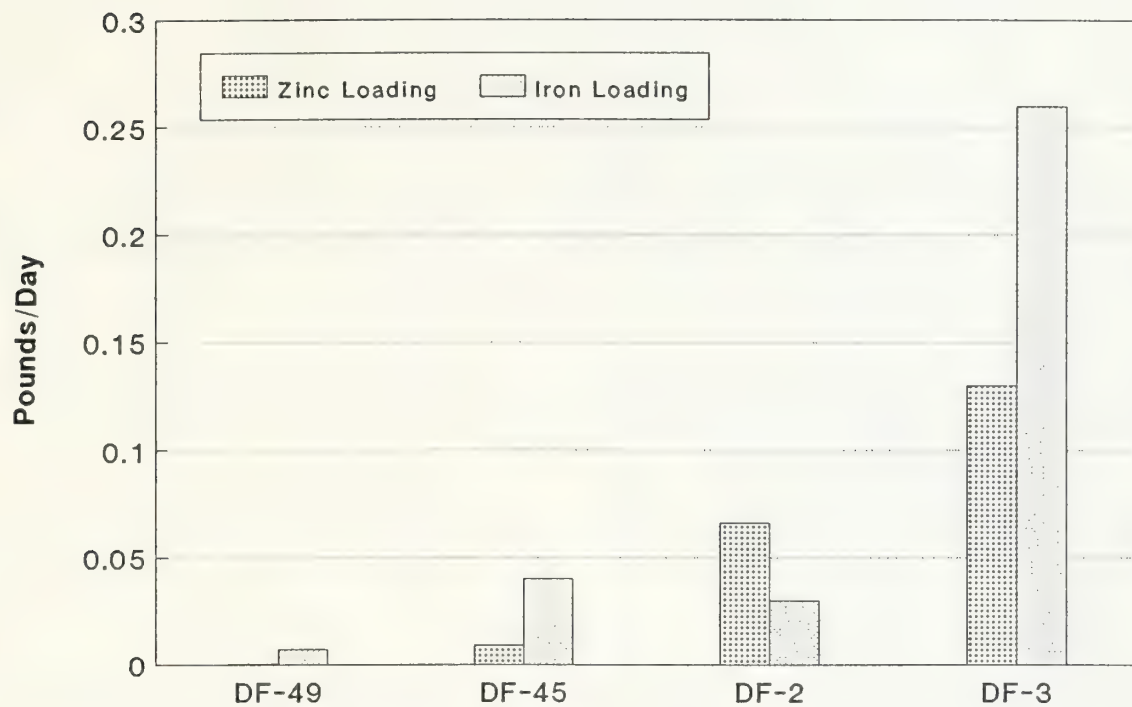
- ◆ Lead loads are generally carried in Galena Creek in the total fraction.
- ◆ Iron and copper loads are primarily transported in the dissolved fraction in the reach of Galena Creek below the Block P Mine. The proportion of dissolved iron and copper as a percentage of the total concentration decreases downstream. It appears the relatively high pH water in the lower half of the stream causes iron and copper to precipitate out of solution and be transported in the system in the total fraction. Iron oxy-hydroxide precipitates visible along Galena Creek are characteristic of this phenomenon.
- ◆ The largest metals loads in Galena Creek are associated with iron, manganese, and zinc.

Metals loading contributed by the point sources sampled during the October, 1990 sampling episode represent a minor percentage of the total load in Galena Creek (Figure 3-24). It is probable that the source which contributes the greatest metals loading to Galena Creek in the study area is acid mine drainage from mine workings associated with the Block P Mine.

DNRC Data

Metals data collected by the DNRC (1977) generally support the spatial trends in metals concentrations and loading in Galena Creek described above. However, through our review of these data, certain characteristics of metals occurrence in Galena Creek are noteworthy.

Metals concentrations at the upper weir on Galena Creek (station DF-7, Figure 3-1) appear to directly correlate with changes in flow at this site. Figures 3-25 and 3-26 illustrate this relationship for total recoverable iron and copper. Such a direct relationship between flow and metals concentrations suggests that disturbed areas above this site are subject to erosion and entrainment by runoff events or high flow conditions in the stream.



Selected Metals Loads from Point Sources; October, 1990
FIGURE 3-24

FIGURE 3-25 TOTAL RECOVERABLE IRON CONCENTRATIONS
AND FLOW DATA; UPPER WEIR ON GALENA CR.

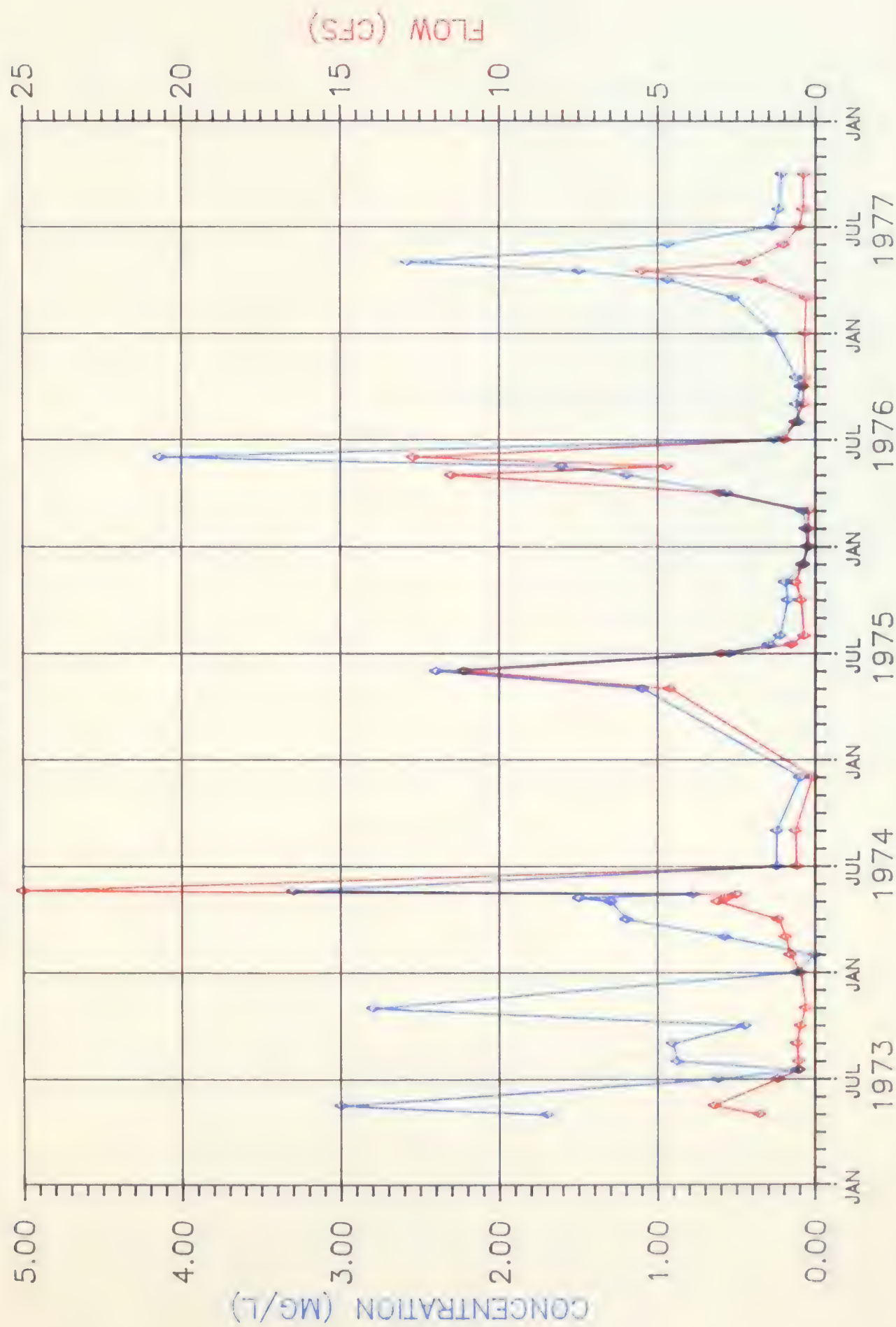
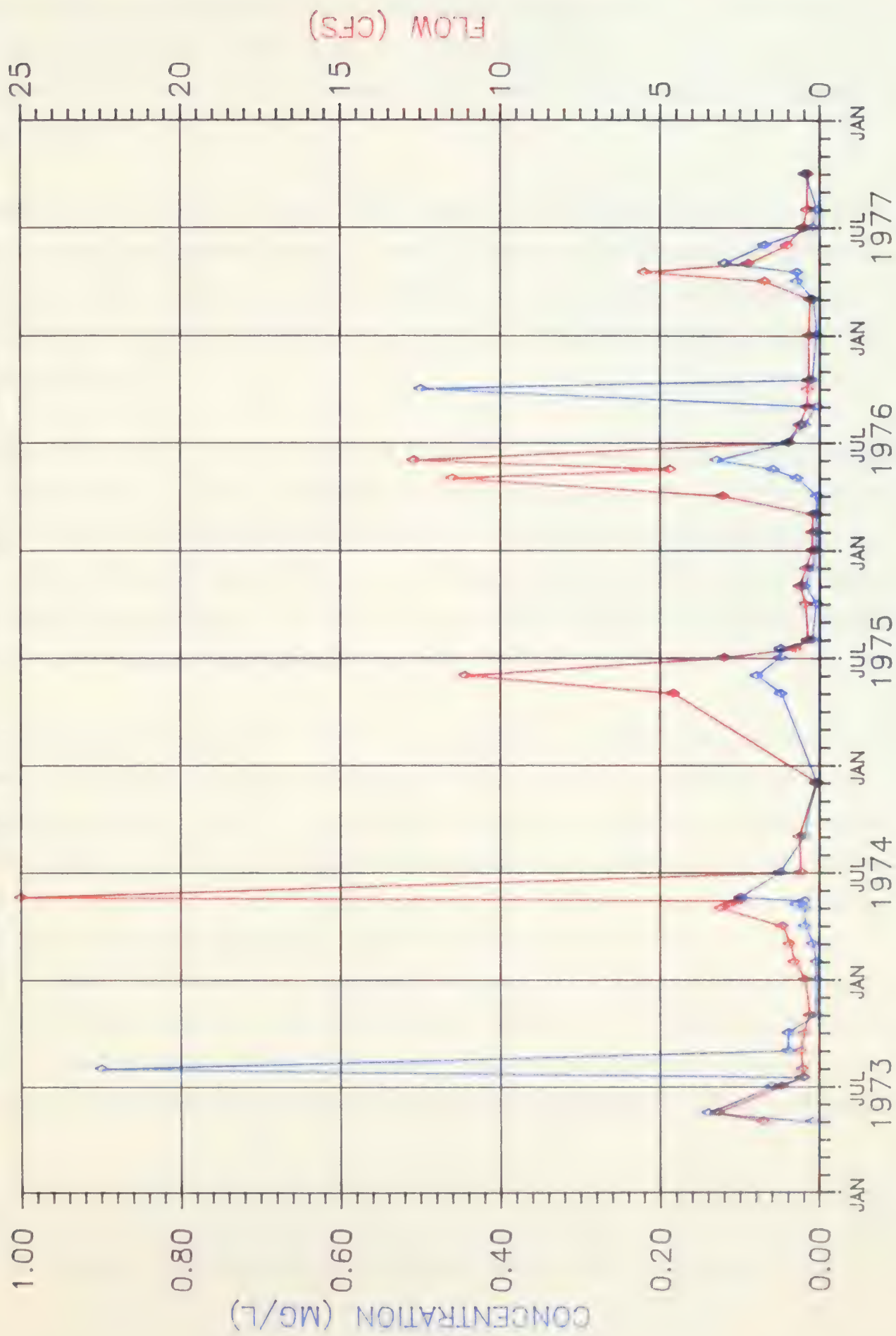


FIGURE 3-26 TOTAL RECOVERABLE COPPER CONCENTRATIONS
AND FLOW DATA; UPPER WEIR ON GALENA CR.



It is likely that the majority of the metals measured at station DF-7 are derived from the upper reaches of Galena Creek (Figure 3-1). Water quality data for Green Creek (Figure 3-1) suggest this tributary contains relatively minor metals concentrations, irrespective of the flow regime.

Discharge from the adit at the Block P mine (station DF-6) occurs seasonally, primarily during the spring and summer months. Peak flow from this adit is about 60 gallons per minute (gpm). Flow ceases during late summer to early fall. Metals concentrations in this adit discharge are inversely related to flow. Figure 3-27 illustrates this relationship for data collected during 1973.

Metals data for surface water station DF-4 (Galena Creek below the Block P Mine and dump) indicate large variations in concentrations have occurred with time. The temporal changes in total recoverable iron concentrations is an example of this variability (Figure 3-28). There is some indication that flow and metals concentrations are inversely related in this reach of Galena Creek. However, there are many exceptions to this relationship where iron concentrations vary greatly during similar flow conditions.

Metals data collected by the DNRC (1977) during previous October sampling events was compared to data derived from the October, 1990 sampling event for four common stations along Galena Creek. All October flow data for the various sites were similar, however a large discrepancy in metals concentrations for station DF-4 was identified through the comparison. Figure 3-29 illustrates this discrepancy for iron. The iron concentration in a sample collected at station DF-4 during October, 1990 was an order-of-magnitude lower than those concentrations measured in samples collected during the same time period in 1976 and 1977. The October, 1990 iron concentration at DF-4 was, however, within the historic concentration range shown on Figure 3-28. The reason for the relatively large temporal variability in metals concentrations at this site is unknown.

Metals concentrations at the lower weir on Galena Creek (station DF-1) generally are inversely related to flow in the stream. This is illustrated by temporal plots of copper and zinc concentrations versus flow (Figures 3-30 and 3-31). This type of relationship

FIGURE 3-27 PLOTS OF SELECTED METALS CONCENTRATIONS, SPECIFIC CONDUCTIVITY, AND FLOW VERSUS TIME IN DISCHARGE FROM THE BLOCK P MINE ADIT IN 1973

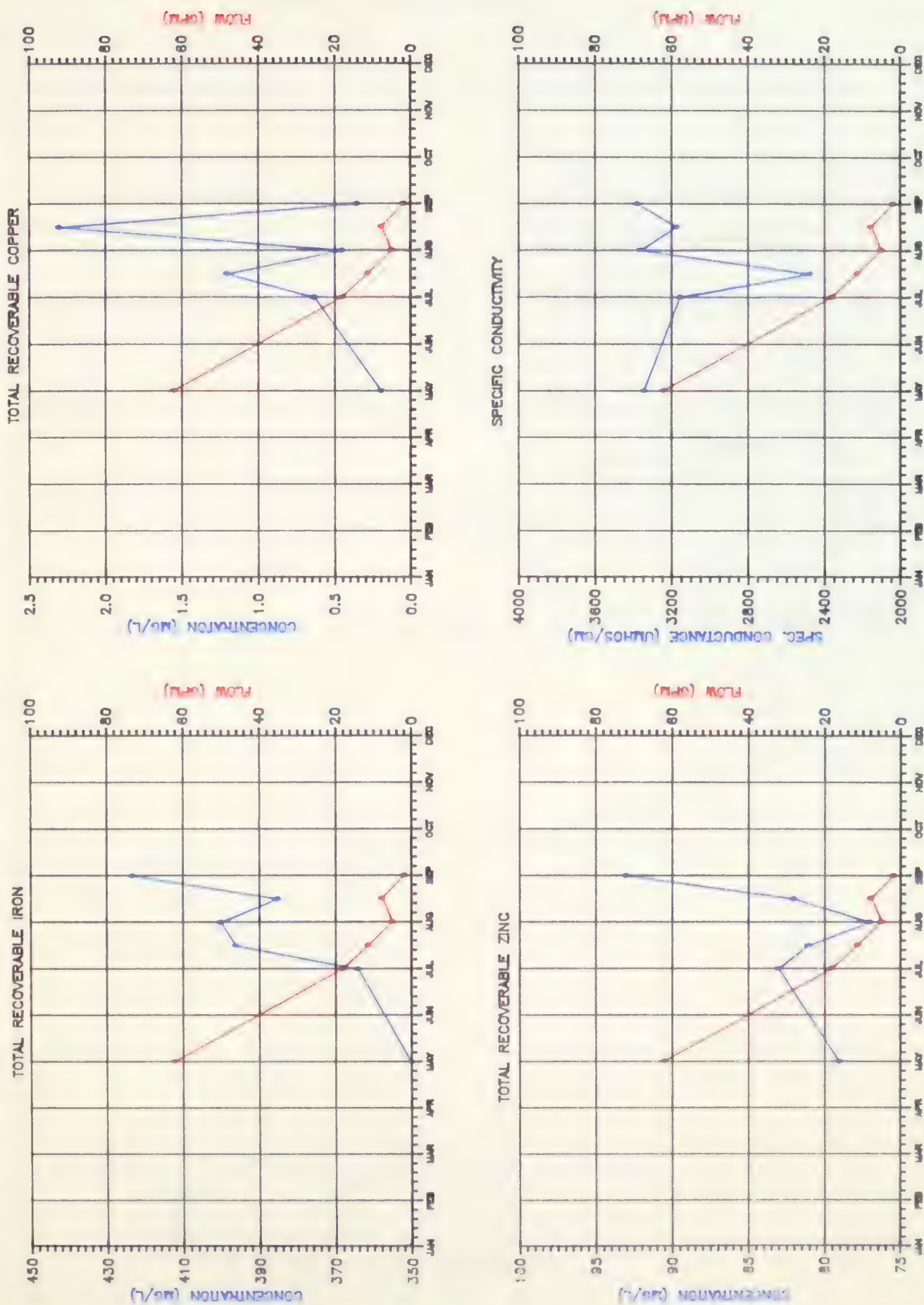


FIGURE 3-28 TOTAL RECOVERABLE IRON AND FLOW AT
AT STATION DF-4 (1973-1977)

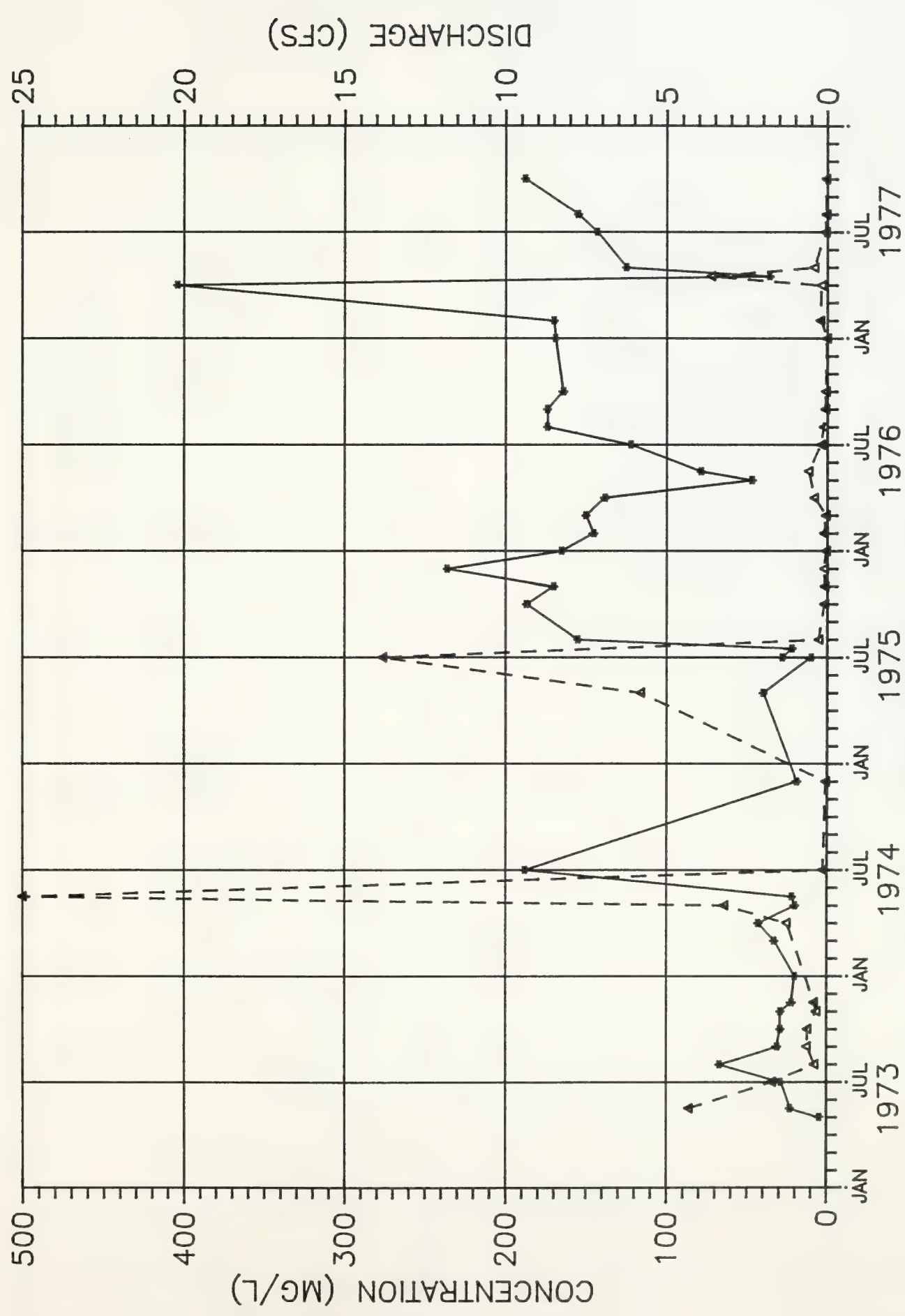


FIGURE 3-29 COMPARISON OF IRON CONCENTRATIONS
IN GALENA CREEK; 1976-1990

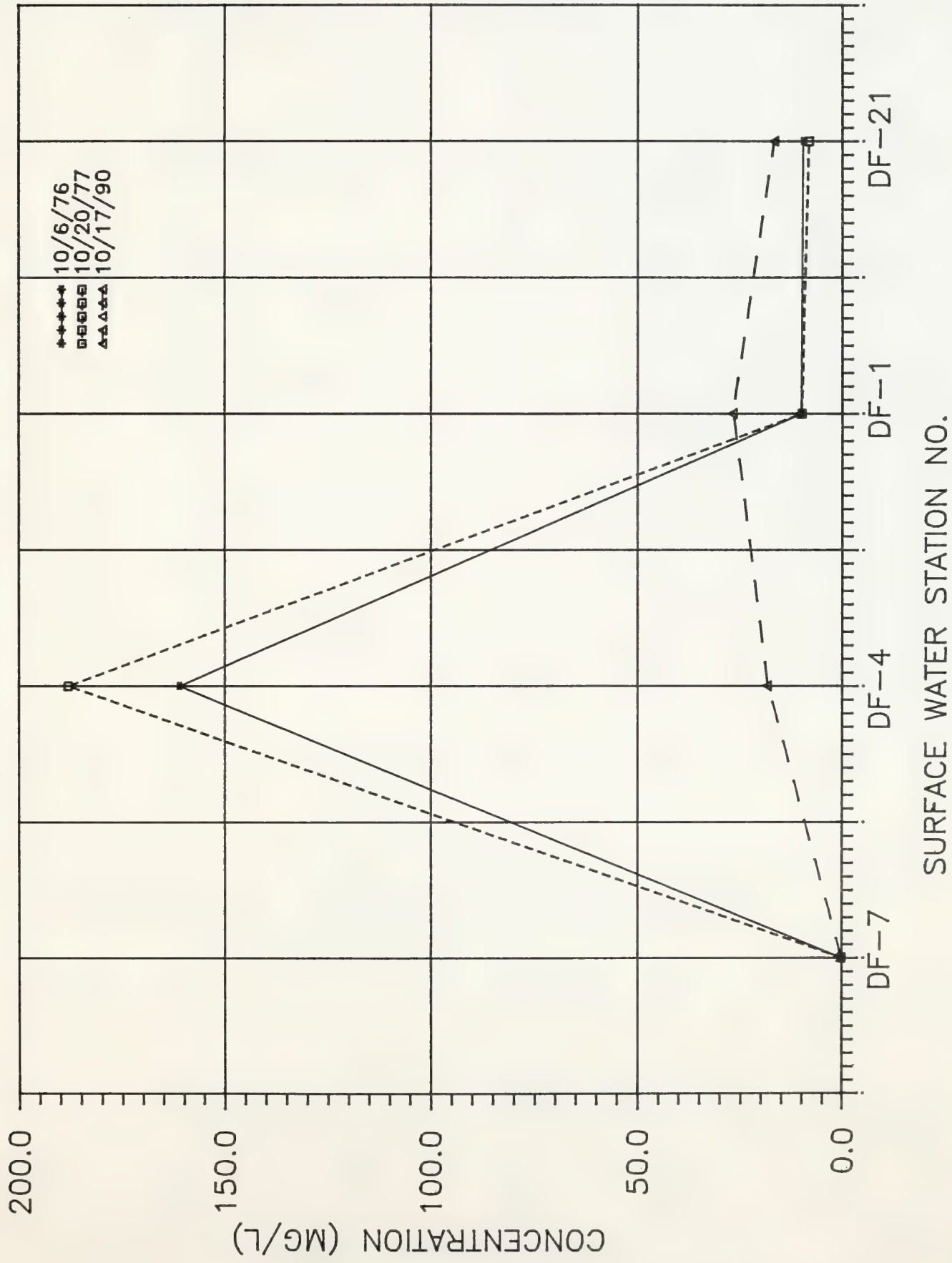


FIGURE 3-30 TOTAL RECOVERABLE COPPER CONCENTRATIONS AND FLOW DATA; LOWER WEIR ON GALENA CR.

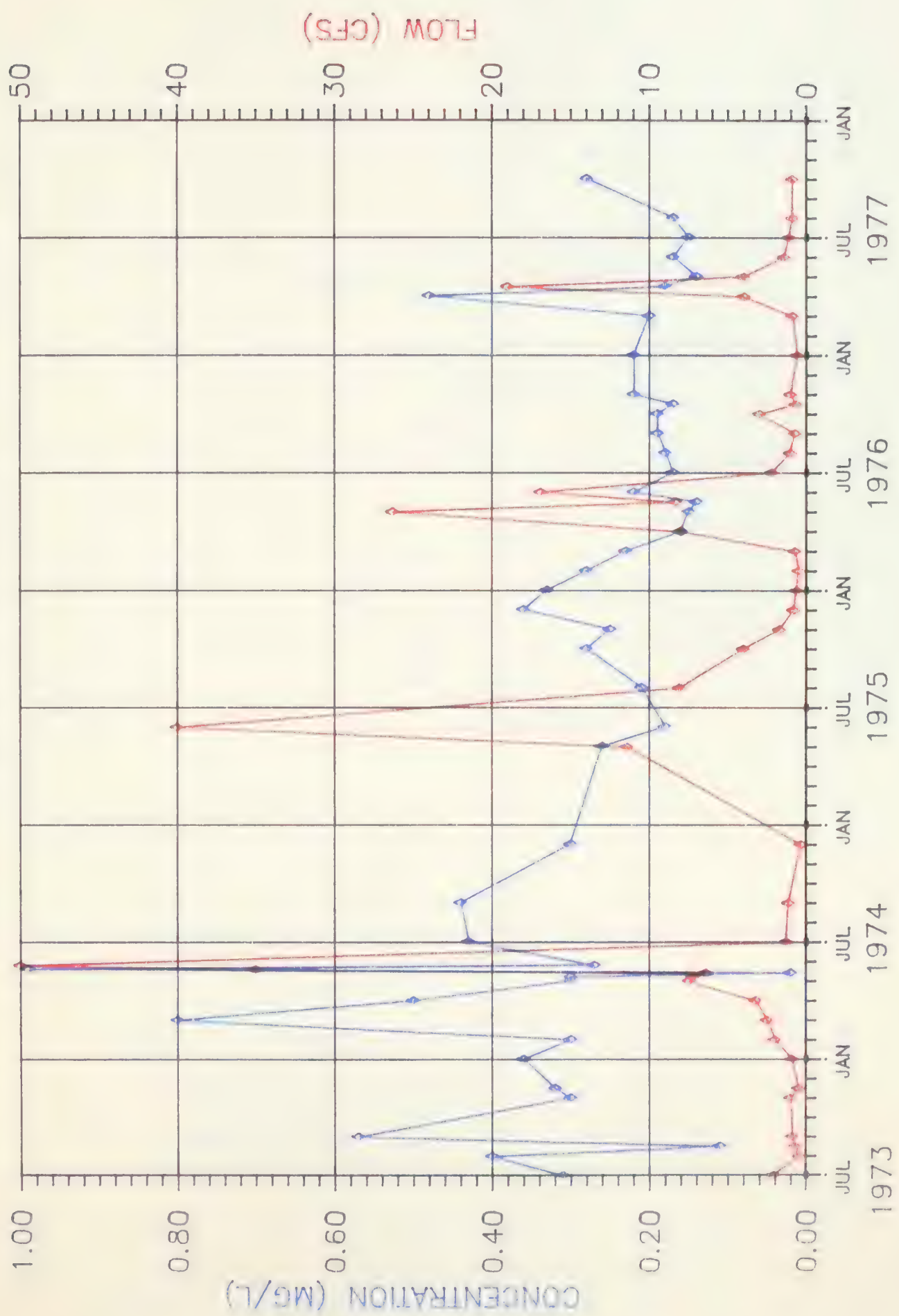


FIGURE 3-31 TOTAL RECOVERABLE ZINC CONCENTRATIONS
AND FLOW DATA; LOWER WEIR ON GALENA CR.

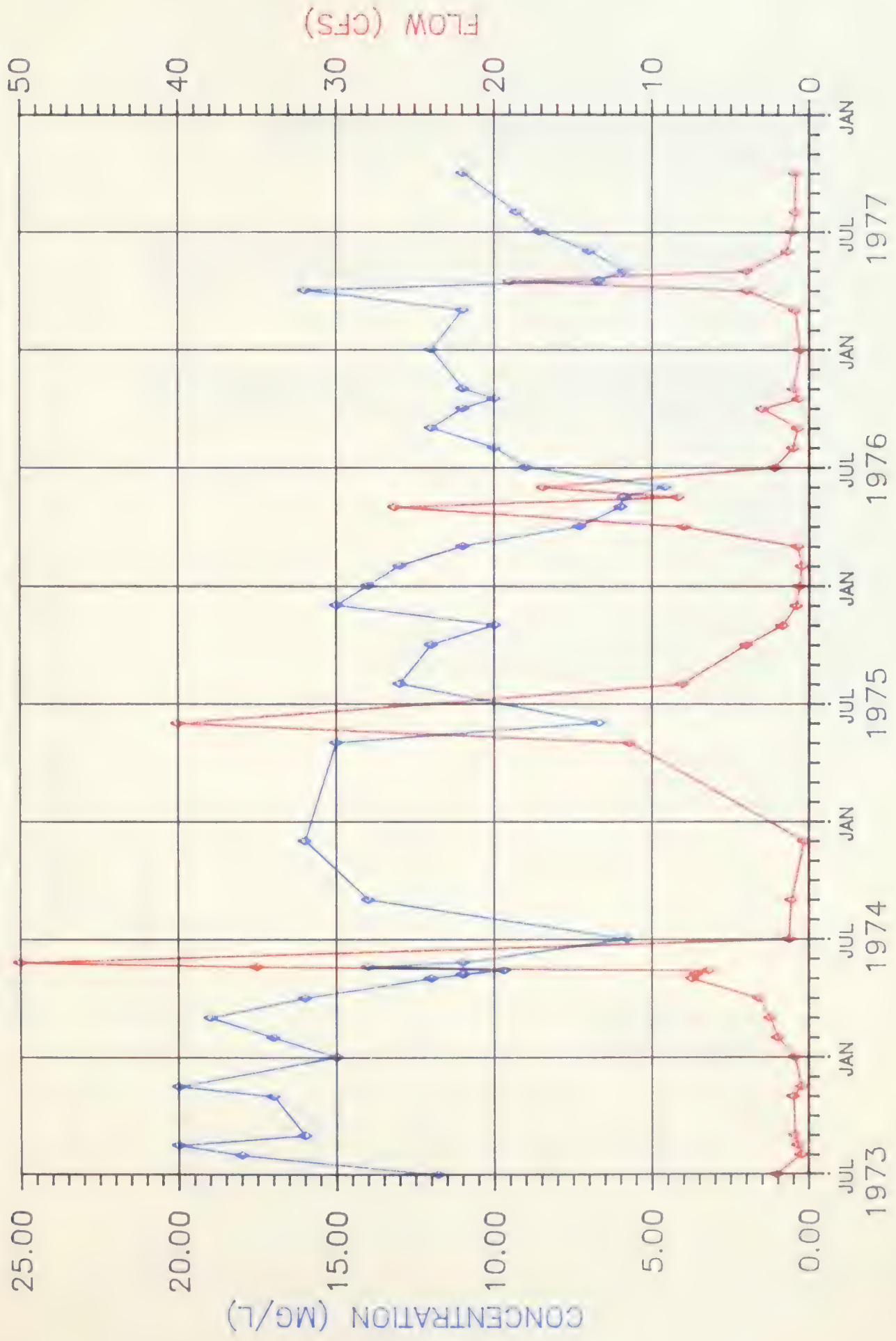
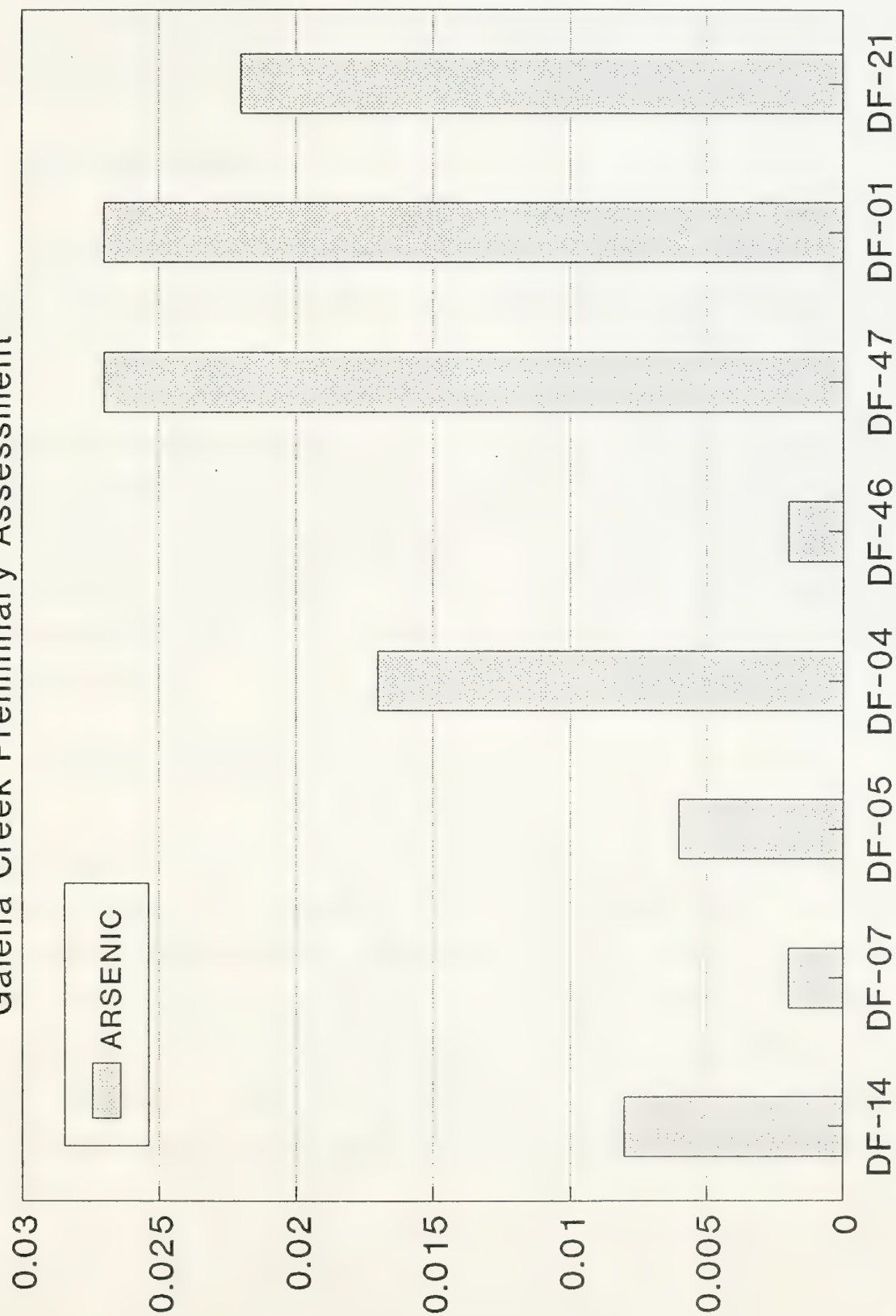


Figure 3-32. Comparison of Arsenic concentrations in
Galena Creek and Water Quality Criteria; October, 1990
Galena Creek Preliminary Assessment



between metals concentrations and flow indicates that an abundance of relatively high quality water enters Galena Creek during runoff events. The runoff water entering Galena Creek above this station dilutes metals concentrations to levels lower than that present during normal flow periods.

3.3.2.4 Other Parameters

Hardness values in samples collected from Galena Creek ranged from 149 to 261 mg/l. Water exhibiting this range of hardness values is classified as hard to very hard (Fetter, 1980).

Nutrient concentrations (measured as nitrate + nitrite as N) in samples from all but two sites were less than the method detection limit of <0.05 mg/l. The Danny T mine seep (DF-3) had a nitrate + nitrite concentration of 0.20 mg/l and the Queen adit discharge (DF-45) contained a concentration of 0.09 mg/l (Appendix A). Both of these concentrations are well below the maximum contaminant level (MCL) established for nitrate + nitrite of 10 mg/l.

3.3.2.5 Water Quality Criteria Exceedances

Figures 3-32 through 3-36 show concentrations of arsenic, cadmium, copper, lead, and zinc in samples collected from Galena Creek during October, 1990 as compared to aquatic water quality criteria (USEPA, 1986) and maximum contaminant levels (USEPA, 1976). Both chronic and acute water quality criteria were exceeded in Galena Creek below the Block P Mine area for cadmium, copper, and zinc. The chronic standard for lead was also exceeded at these stations. The MCLs for lead (0.05 mg/l) and cadmium (0.01 mg/l) were exceeded at stations sampled in the lower half of the drainage.

Figure 3-33. Comparison of Cadmium Concentrations in Galena Creek and Water Quality Criteria; October, 1990
Galena Creek Preliminary Assessment



Figure 3-34. Comparison of Copper Concentrations in
Galena Creek and Water Quality Criteria; October, 1990
Galena Creek Preliminary Assessment

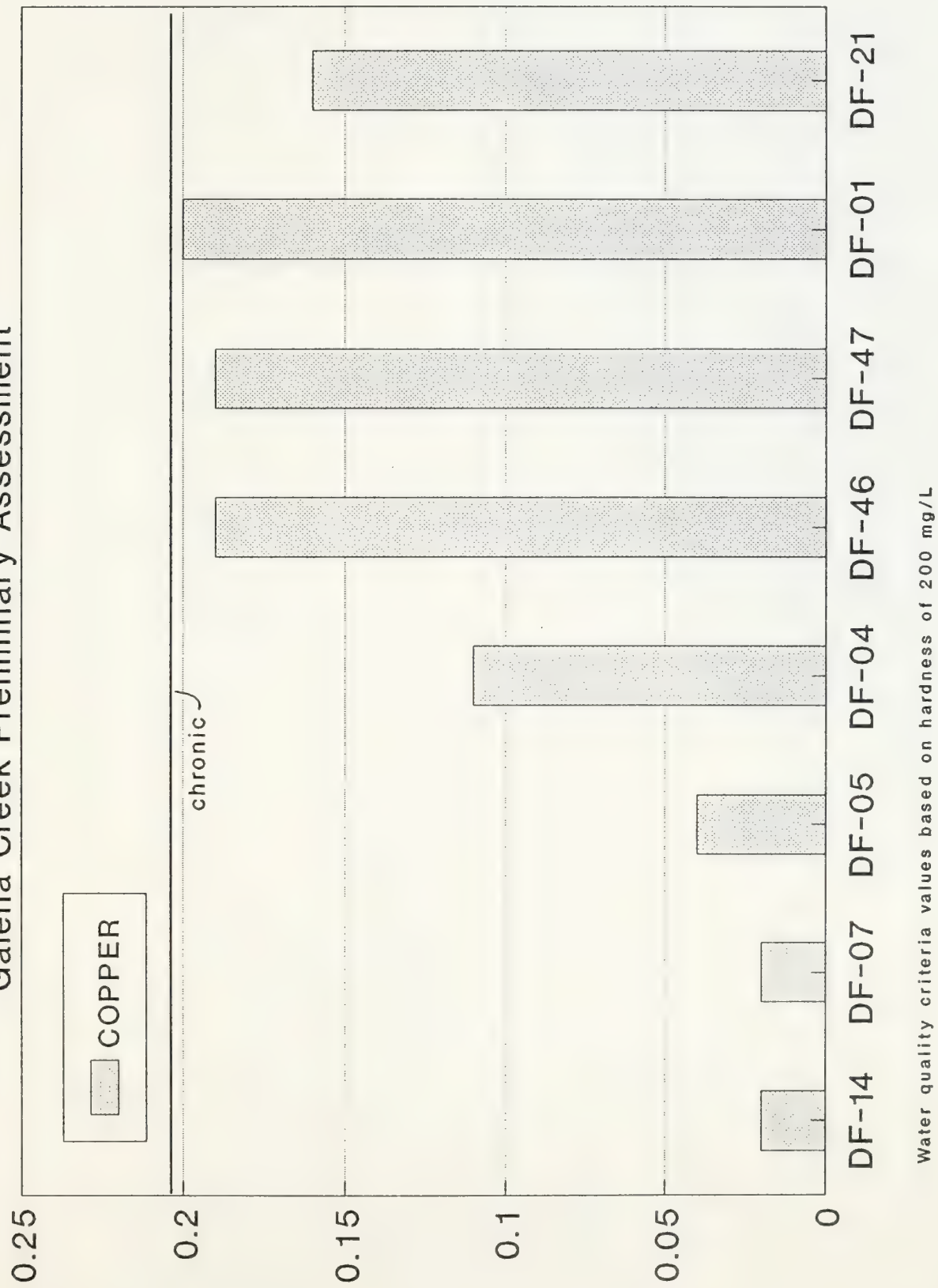


Figure 3-35. Comparison of Lead Concentrations in
Galena Creek and Water Quality Criteria; October, 1990
Galena Creek Preliminary Assessment

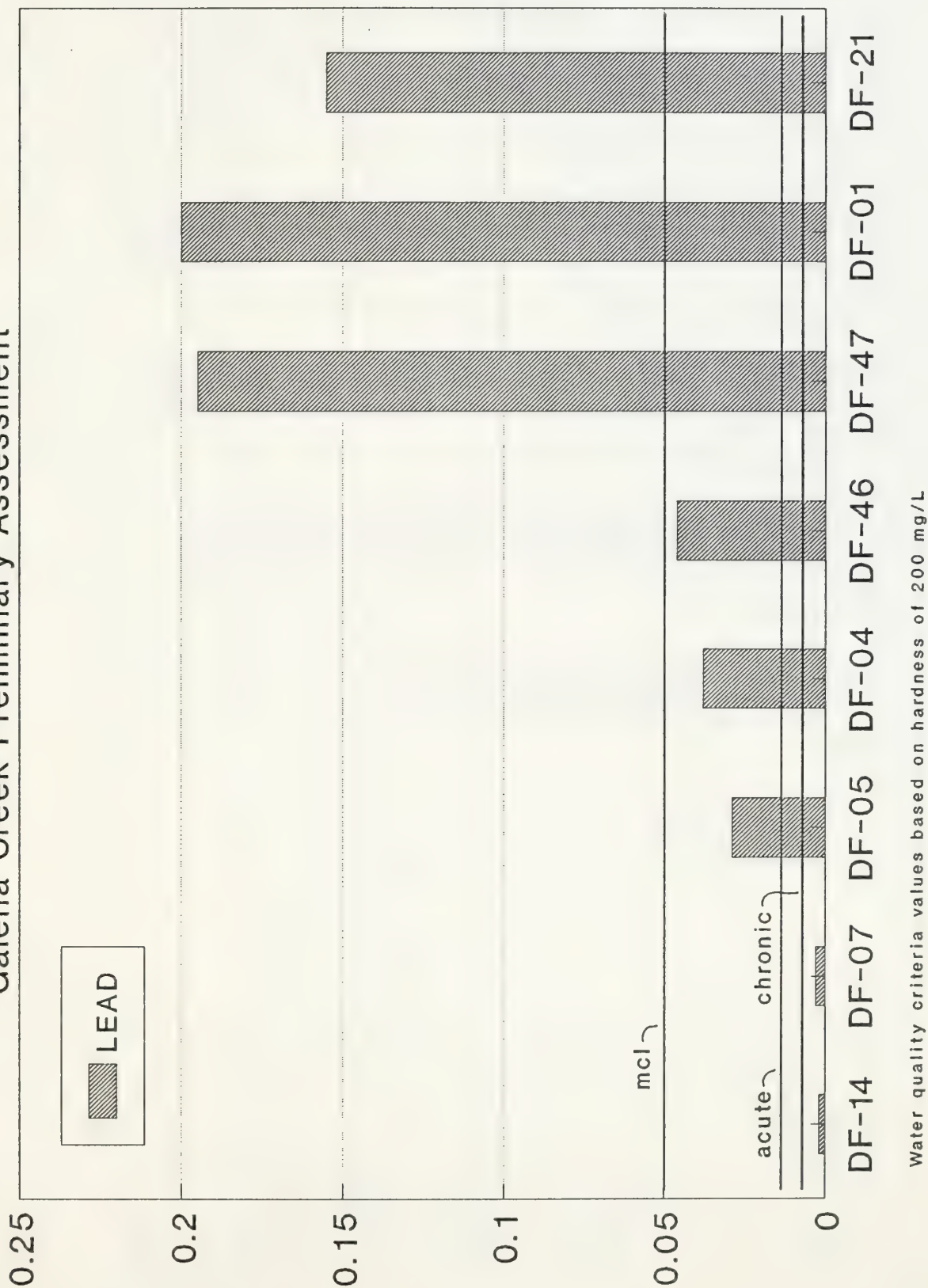
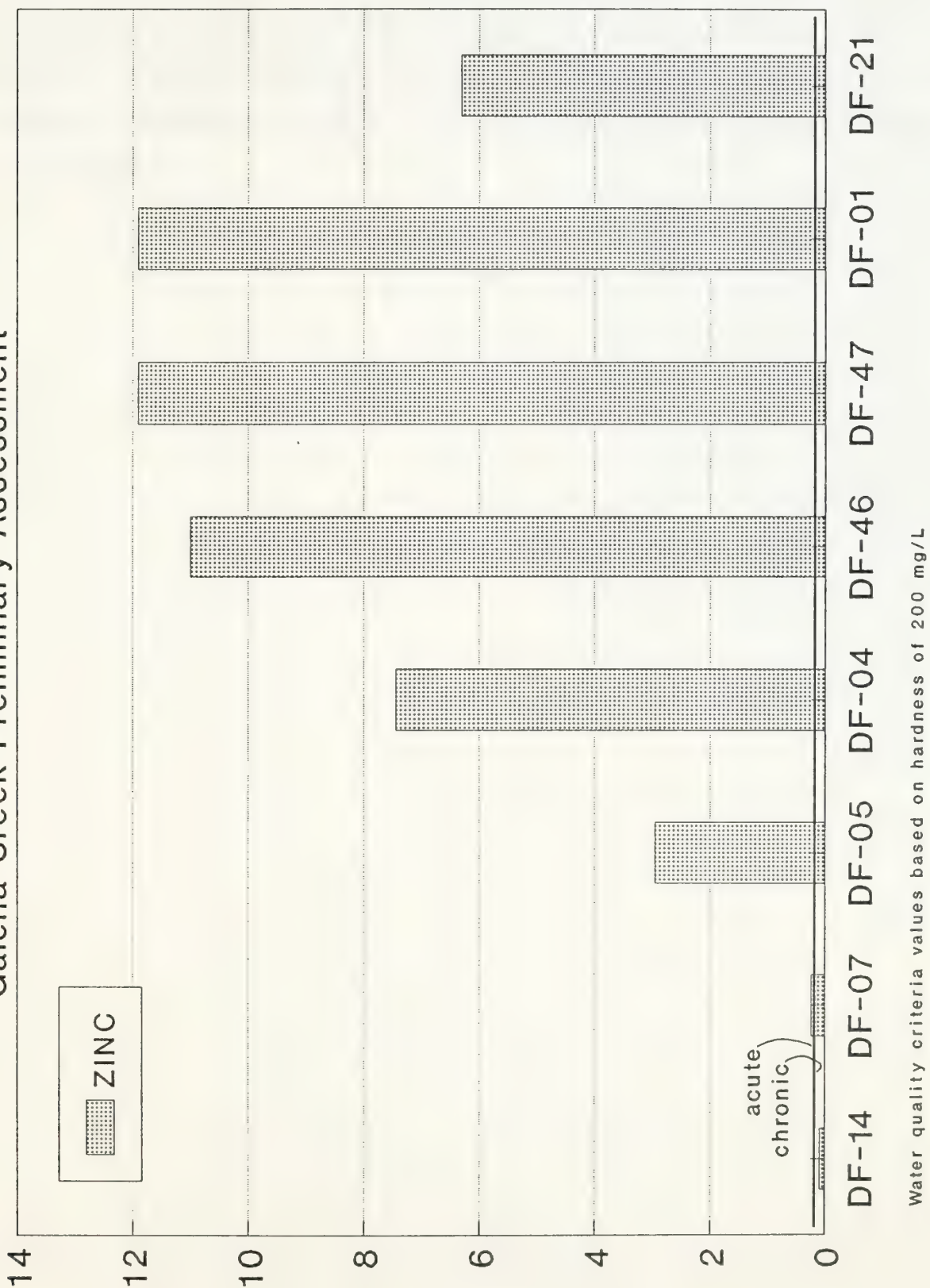


Figure 3-36. Comparison of Zinc Concentrations in
Galena Creek and Water Quality Criteria; October, 1990
Galena Creek Preliminary Assessment



Silver Creek (DF-2), the Queen adit discharge (DF-45), and the Danny T Mine adit discharge (DF-3) all exceeded both chronic and acute aquatic life standards for cadmium, copper, and zinc and the chronic standard for lead. Samples from these sites also exceeded the MCLs for lead and cadmium. In addition, the Queen adit discharge (DF-45) exceeded the MCL for arsenic (0.05 mg/l). The Carter Mine adit discharge (DF-49) did not exceed any standards.

4.0 GROUNDWATER INVESTIGATION

4.1 METHODS

Chen-Northern hydrogeologists installed seven monitoring wells throughout the study area in conjunction with this PA. Groundwater samples were collected from each of these monitoring wells, one domestic well located in Barker, and one monitoring well previously installed by Amax. Each groundwater sample was analyzed for a suite of parameters by Chen-Northern's laboratory in Billings, Montana.

Field personnel also measured water levels in all wells in the area and completed a limited level survey of designated measuring points on selected wells. Finally, a hydrogeologist completed slug tests in six of the monitoring wells installed by Chen-Northern to qualitatively assess the hydraulic conductivity of water-bearing material associated with each well completion. Detailed descriptions of methods used to perform these field activities are provided in the following sections.

4.1.1 Monitoring Well Siting

Chen-Northern project hydrogeologists installed seven monitoring wells within the study area. These wells were installed in order to preliminarily characterize the hydrogeologic system in the Barker/Hughesville area and provide groundwater chemistry data for areas both upgradient and downgradient of the Block P Mine dump and the Block P Mill tailings. In addition, one monitoring well was sited immediately adjacent to Galena Creek near Barker and another immediately adjacent to the Dry Fork of Belt Creek to evaluate the relationship between surface water and groundwater chemistry in these areas. All monitoring wells were drilled to depths such that the uppermost water-bearing zone at each location could be characterized.

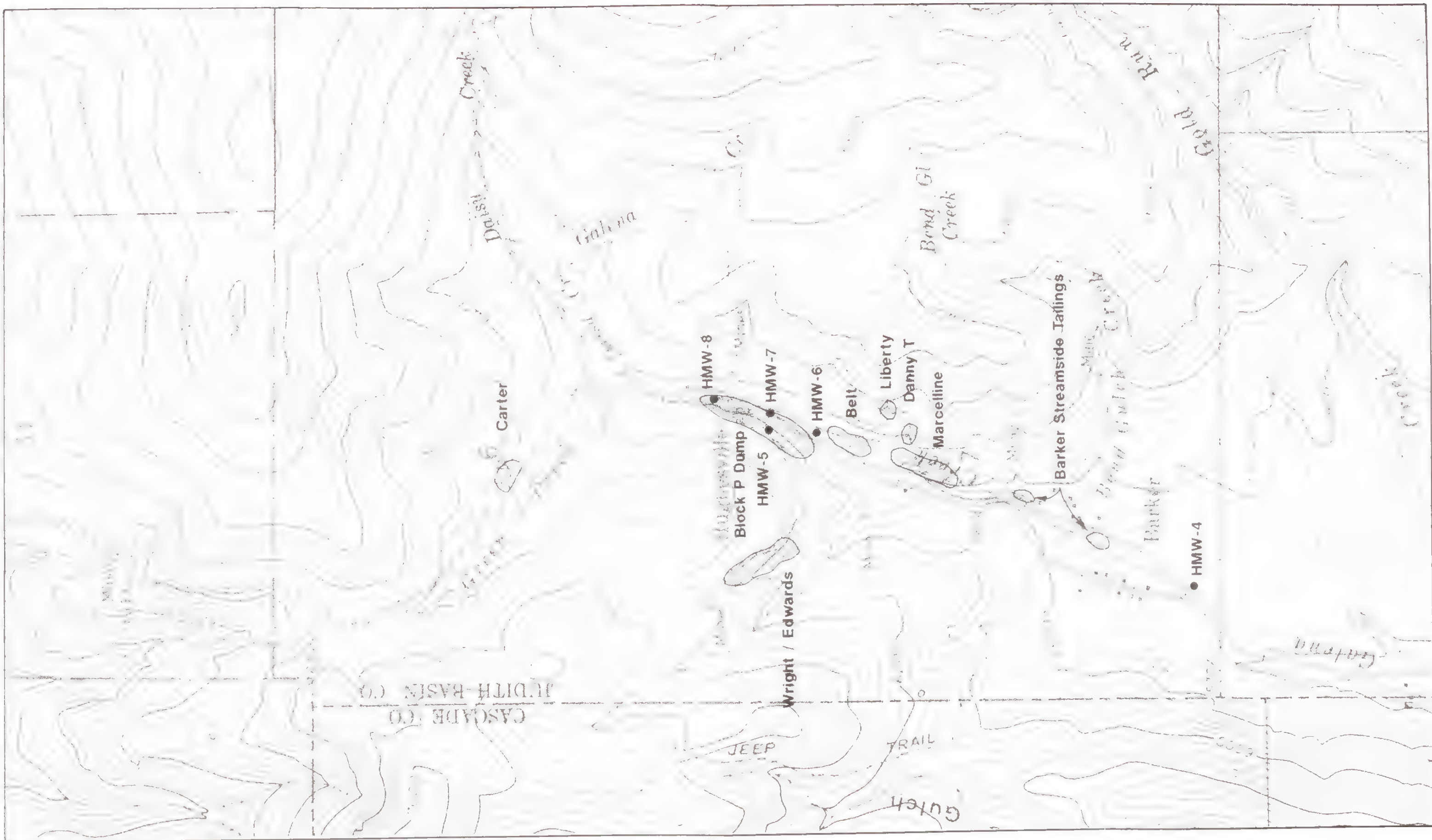
4.1.2 Monitoring Well Installation

Chen-Northern hydrogeologists installed seven monitoring wells in the study area during November, 1990 (Figure 4-1). The wells were installed using an air rotary rig with either a 5 7/8-inch diameter percussion bit or a 5 7/8-inch diameter tri-cone bit. Six-inch diameter steel casing was advanced with the drill bit through unconsolidated material to prevent borehole collapse. If bedrock was encountered in the boreholes, the drill bit was advanced in an open hole. Chen-Northern hydrogeologists visually examined drill cuttings to characterize the subsurface lithology. Lithologic information was recorded on well logs.

When the target depth of the borehole was reached, flush-threaded Schedule 40 PVC casing was inserted into the temporary steel casing. All monitoring wells were completed with two-inch diameter casing with the exception of monitoring well HMW-5. Well HMW-5 was installed to a depth of approximately 107 feet below ground surface and completed with four-inch diameter casing. Four inch PVC casing was used to prevent the casing from bowing in the borehole. Factory-slotted (0.020 inch slot) casing was incorporated into the casing column at depths coincident with the uppermost water-bearing unit. Flush threaded bottom caps were fitted to the bottom of each PVC casing column.

The annular space between the borehole wall and the perforated interval of the PVC casing was backfilled with chemically inert Colorado silica sand (10-20 mesh) to form a filter pack. The sand was added to the annular space from the bottom of the borehole to approximately two feet above the perforated interval of the PVC. The annular space above the filter pack was backfilled with granular bentonite to within three feet of ground surface to create a low-permeability annular seal.

The temporary steel casing was withdrawn from the borehole at a rate coincident with the rate with which the well annulus was backfilled. The wells were finished at the surface by cementing a five-foot section of six-inch diameter steel casing about the PVC. The steel casing was then fitted with a locking lid. Figure 4-2 is a schematic of well completions used during the PA. Monitoring well lithologic and completion logs are contained in Appendix B-1.



- Monitoring Well
- Proposed Soil/Mine Waste Sampling Areas

Monitoring Well Locations
Galena Creek Preliminary Assessment
FIGURE 4-1 (sheet 1 of 2)

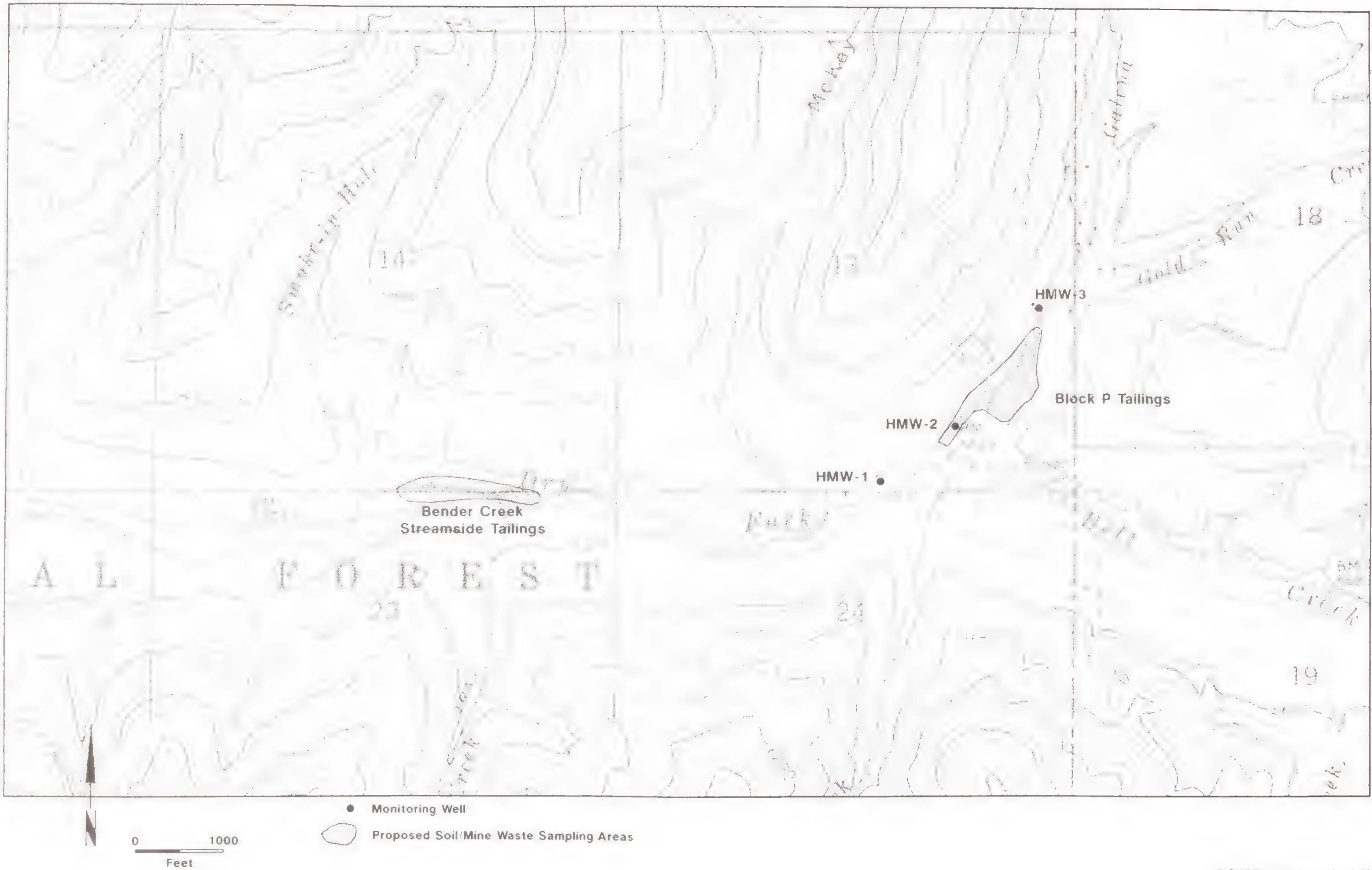
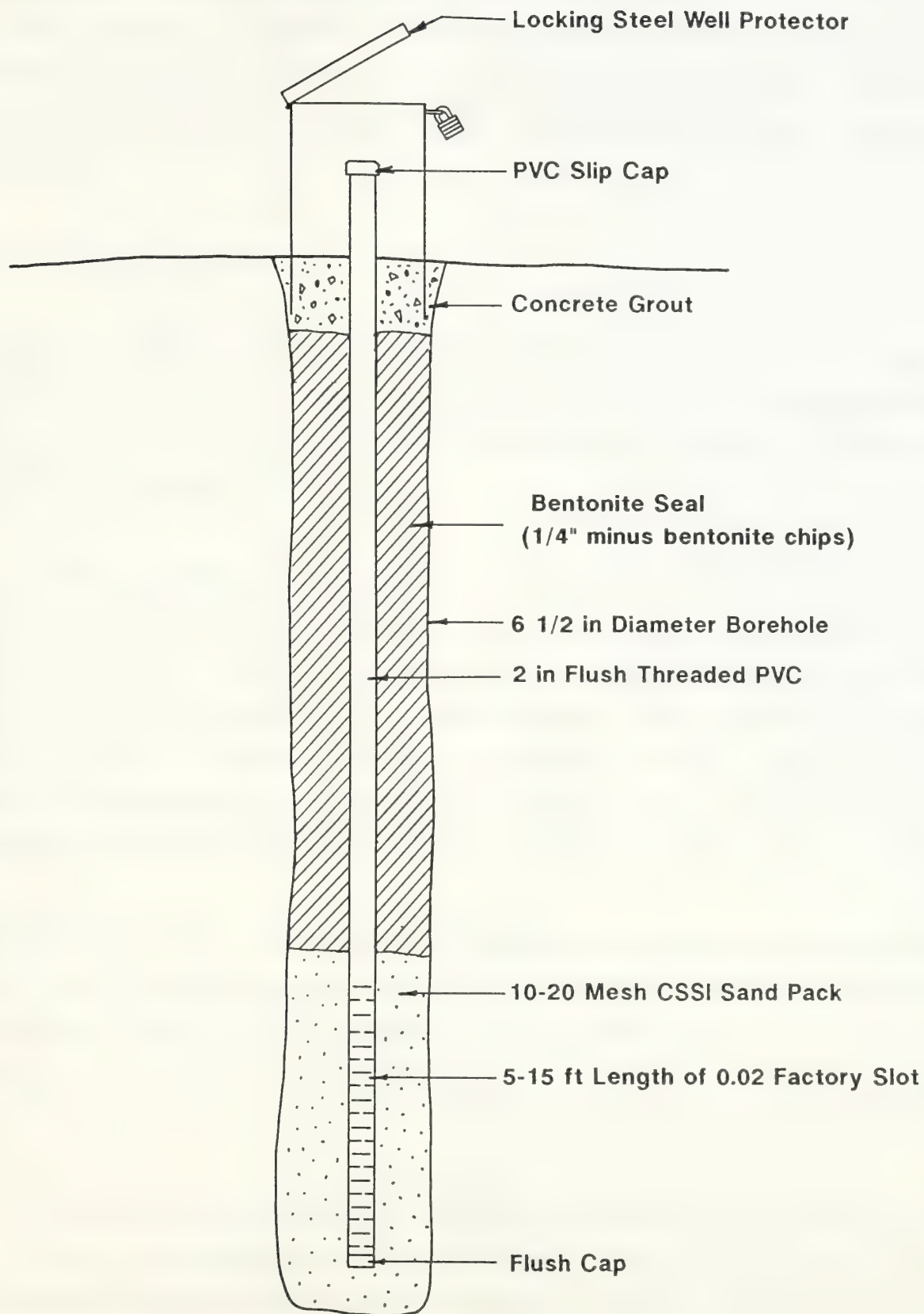


FIGURE 4-1 (sheet 2 of 2)



Schmatic of Typical Monitoring Well Design
Galena Creek Preliminary Assessment
FIGURE 4-2

Each monitoring well was developed following installation. The purpose of developing the wells was to improve the hydraulic connection between the wellbore and the adjacent water-bearing unit and to remove any drilling debris from the well casing. Development was performed by bailing and surging the wells until relatively clear water was obtained from each well.

4.1.3 Groundwater Sampling

Hydrologic technicians collected groundwater samples from each of the seven monitoring wells installed on November 14 and 15, 1990. Technicians also sampled Ms. Gwen McBride's domestic well, located in Barker (Figure 4-1) and a monitoring well previously installed by Amax (Amax-2; Figure 4-1).

Field technicians purged each well using a decontaminated, hand-lift pump. When possible, at least three casing volumes of water were removed from each well prior to collecting the samples. Those wells which would not yield three casing volumes of water were bailed dry and sampled as the wells recovered. Field technicians monitored temperature, pH, and specific electrical conductance while purging each well. Groundwater samples were collected after three casing volumes were evacuated or when two consecutive field parameter measurements varied by less than 5%.

We obtained groundwater samples using the hand-lift pump. Samples were prepared and preserved according to procedures presented in the project sampling and analysis plan (Chen-Northern, 1990). Field parameters including temperature, pH, and specific electrical conductivity were measured immediately upon sampling and recorded on field forms.

Field technicians also prepared quality control/quality assurance (QA/QC) samples in the field for inclusion in the sample train. QA/QC samples consisted of duplicate samples, cross-contamination blanks, and blind field standards. Two sets of these samples were prepared and submitted to the laboratory blind during the November, 1990 groundwater monitoring event.

Necessary paperwork was completed in the field in accordance with the project sampling and analysis plan. Sample coolers and corresponding paper work were then shipped to Chen-Northern's laboratory in Billings, Montana for analysis. Parameters included in laboratory analyses are listed in Table 4-1.

TABLE 4-1
GROUNDWATER PARAMETER LIST;
GALENA CREEK PRELIMINARY ASSESSMENT

FIELD PARAMETERS

Temperature
pH
Specific Conductivity

LABORATORY PARAMETERS

	<u>Dissolved Metals</u>
Temperature	Aluminum
pH	Arsenic
Specific Conductivity	Barium
Total Dissolved Solids	Cadmium
Sodium Adsorption Ratio	Chromium
Total Hardness as CaCO3	Copper
Calcium	Iron
Magnesium	Lead
Sodium	Manganese
Potassium	Mercury
Total Alkalinity as CaCO3	Nickel
Bicarbonate Alkalinity as HCO3	Selenium
Carbonate Alkalinity as CO3	Silver
Hydroxide Alkalinity as OH	Zinc
Chloride	
Fluoride	
Nitrate + Nitrite as N	
Sulfate	

4.1.4 Water Level Measurement

Chen-Northern hydrogeologists measured depth to groundwater in all monitoring wells installed during this investigation. Water levels were measured from designated measuring points (located on the north quadrant of the top of the steel well protector) using a decontaminated electric well probe. Measurements were made to the nearest hundredth of a foot and recorded on field forms.

4.1.5 Survey

Chen-Northern project scientists completed a level survey in the Hughesville/Barker area on November 13, 1990. The purpose of the survey was to determine relative elevations of water levels in wells proximal to each other and to determine the elevation of groundwater relative to adjacent surface water courses. These data were intended to provide information to evaluate the influent-effluent characteristics of Galena Creek and the Dry Fork of Belt Creek.

4.1.6 Aquifer Testing

Chen-Northern's project hydrogeologist completed slug-tests in each of the seven monitoring wells installed during this PA on November 26, 1990. The slug-tests were performed to characterize the hydraulic conductivity of water-bearing units associated with each well completion. These data were used to evaluate groundwater flow rates and effects on receiving surface water systems.

Slug-tests were performed by first measuring the depth to water in each well. A pressure transducer coupled to a digital recorder was then lowered into the saturated portion of the well casing and left until the water level stabilized. The hydrogeologist then quickly lowered a solid cylindrical tube into the well bore, causing a sudden water level rise. Subsequent falling water levels were recorded by the digital recorder at approximately five second time intervals. Once water levels in the well bore had subsided to static conditions, the cylindrical apparatus was quickly removed from the well, causing a sudden

drop in water level. These water level recovery rates were also recorded by the digital recorder. The two types of tests (slug-in and slug-out) provided a means to complete a duplicate test at each well.

Slug-test data were analyzed using methods described by Bouwer and Rice (1976). This method is designed to calculate hydraulic conductivity values with data collected from partially penetrating wells completed in unconfined aquifers.

4.2 CHANGES TO THE PROJECT SAMPLING AND ANALYSIS PLAN

There were no substantial changes to the project sampling and analysis plan (Chen-Northern, 1990b). However, attempts were made to install one shallow monitoring well adjacent to Galena Creek at the toe of the Block P dump. Monitoring well HMW-7 (Figure 4-1) was installed by hand augering a shallow borehole to groundwater and then driving a PVC sandpoint as deep as possible. The well penetrated the water table approximately one foot. However, the usefulness of this well was limited because the internal diameter of the PVC (one-inch) and the low yield from the sandpoint precluded collection of a groundwater sample.

4.3 PRESENTATION AND INTERPRETATION OF DATA

This section presents and summarizes data collected during the groundwater investigation associated with the PA. Interpretations of these data are also included in this section.

4.3.1 Monitoring Well Installation

4.3.1.1 Lithology

Lithologic units encountered while drilling included mine waste rock, mill tailings, poorly sorted alluvial sediments, and syenite and limestone bedrock. The occurrence of any of these materials in a particular borehole was subject to the proximity of the drill holes to historic mining areas and the location of the drill site with respect to the regional stratigraphy.

Monitoring well HMW-5 was installed on top of the Block P mine dump approximately 100 feet east of Galena Creek (Figure 4-1). This well penetrated approximately 35 feet of waste rock associated with the Block P mine dump (Appendix B-1). The waste rock encountered was highly oxidized, medium to coarse-grained, and dry. Based on our visual examination of drill cuttings, native colluvial material was not present beneath the waste rock. Competent, aphanitic intrusive rhyolite was encountered immediately beneath the waste rock. Crystalline syenite was encountered at a depth of approximately 53 feet below ground surface. Groundwater was encountered in borehole HMW-5 at a depth of approximately 95 feet below ground surface.

Monitoring well HMW-2 was installed immediately downgradient of the Block P Mill tailings upstream from the confluence of the Galena Creek and Dry Fork of Belt Creek (Figure 4-1). Borehole HMW-2 encountered approximately four feet of mill tailings material overlying moderately well-sorted alluvial material. Alluvial sediments primarily consist of coarse-grained, highly oxidized clasts. Water was encountered in the borehole at a depth of approximately four feet below ground surface. The borehole penetrated limestone bedrock at a depth of approximately eight feet below ground surface. This limestone unit is believed to be associated with the Cambrian Pilgrim Formation (Whitkind, 1971).

Monitoring wells HMW-3, HMW-4, HMW-6, and HMW-8 were installed adjacent to Galena Creek (Figure 4-1). These wells penetrated eight to 14 feet of alluvial sediments associated with Galena Creek. Alluvial sediments identified in each of these boreholes were typically poorly sorted, coarse-grained gravels. Syenite bedrock was encountered beneath the alluvial sediments in wells HMW-4, HMW-6, and HMW-8. Limestone bedrock was encountered beneath the alluvial sediments in monitoring well HMW-3.

Monitoring well HMW-1 was sited adjacent to the Dry Fork of Belt Creek below its confluence with Galena Creek (Figure 4-1). The borehole drilled for well HMW-1 penetrated approximately 11 feet of very coarse-grained alluvial sediments with many cobbles and boulders. Limestone bedrock thought to be the Pilgrim Formation was encountered beneath the alluvium at this location.

4.3.1.2 Monitoring Well Completion

The primary focus of groundwater investigations associated with this PA was to determine the characteristics of the shallow water-bearing units. For this reason, all monitoring wells installed in conjunction with this investigation were completed in the upper five to ten feet of the first water-bearing unit encountered during drilling.

Monitoring well HMW-5 (Figure 4-1) was the deepest monitoring well installed during this investigation. The primary objective of installing this well on top of the Block P Mine waste dump was to determine if groundwater was in contact with waste rock materials in the dump. Since groundwater was encountered at a depth of approximately 95 feet below the top of the dump, within syenite bedrock, the Block P Mine dump does not appear to be within the influence of groundwater at this location.

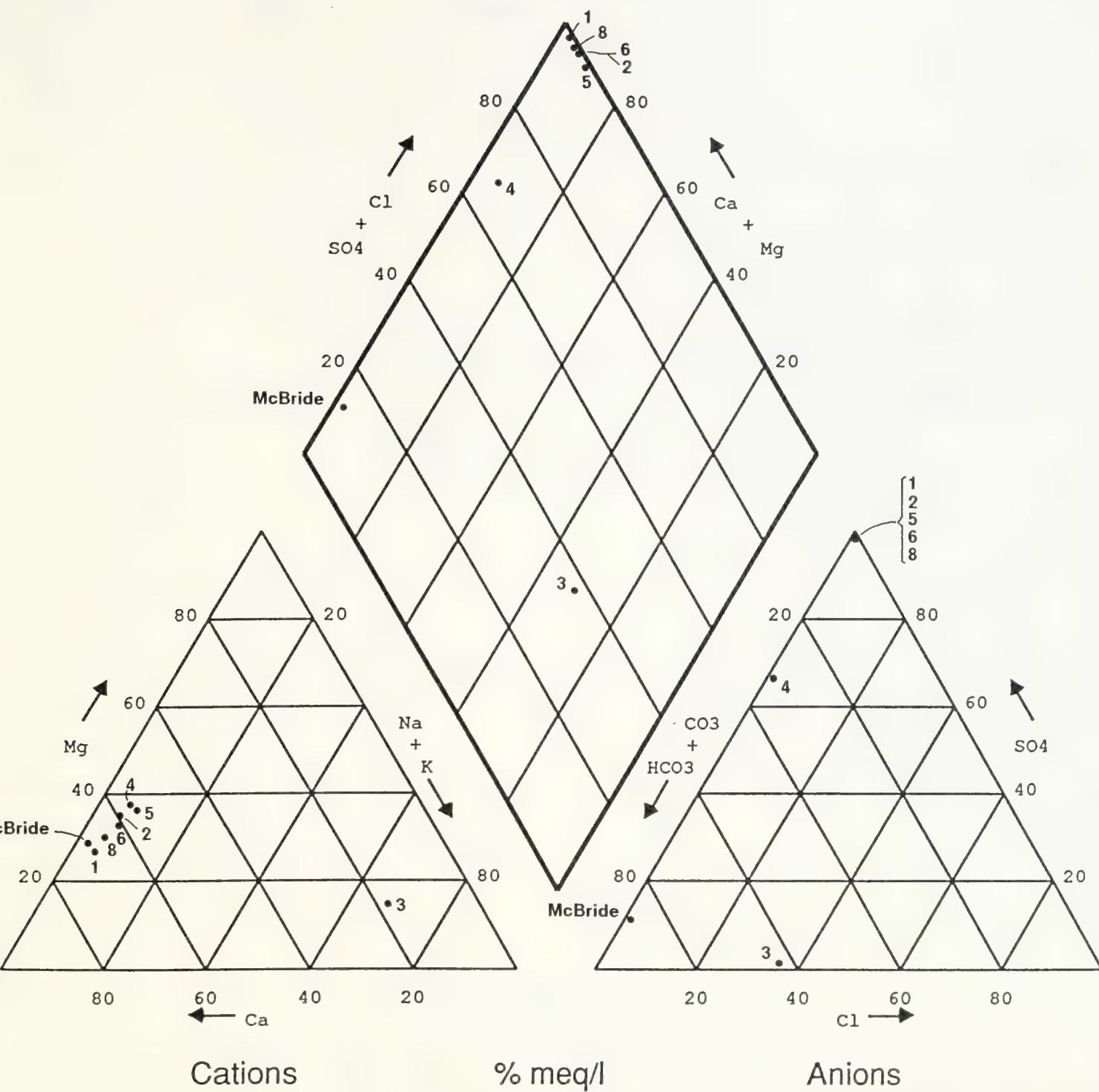
Monitoring well HMW-3 (Figure 4-1) was installed adjacent to Galena Creek upstream from the Block P mill tailings. Limestone bedrock was encountered at this location at a depth of approximately nine feet below ground surface. With no indication that groundwater was present within the alluvial material, the borehole was advanced to a depth of 60 feet below ground surface. Groundwater was not encountered at this depth. The well was subsequently backfilled and completed with a screened interval extending from 12 to 22 feet below ground surface to monitor conditions near the alluvium/limestone contact.

4.3.2 Groundwater Quality

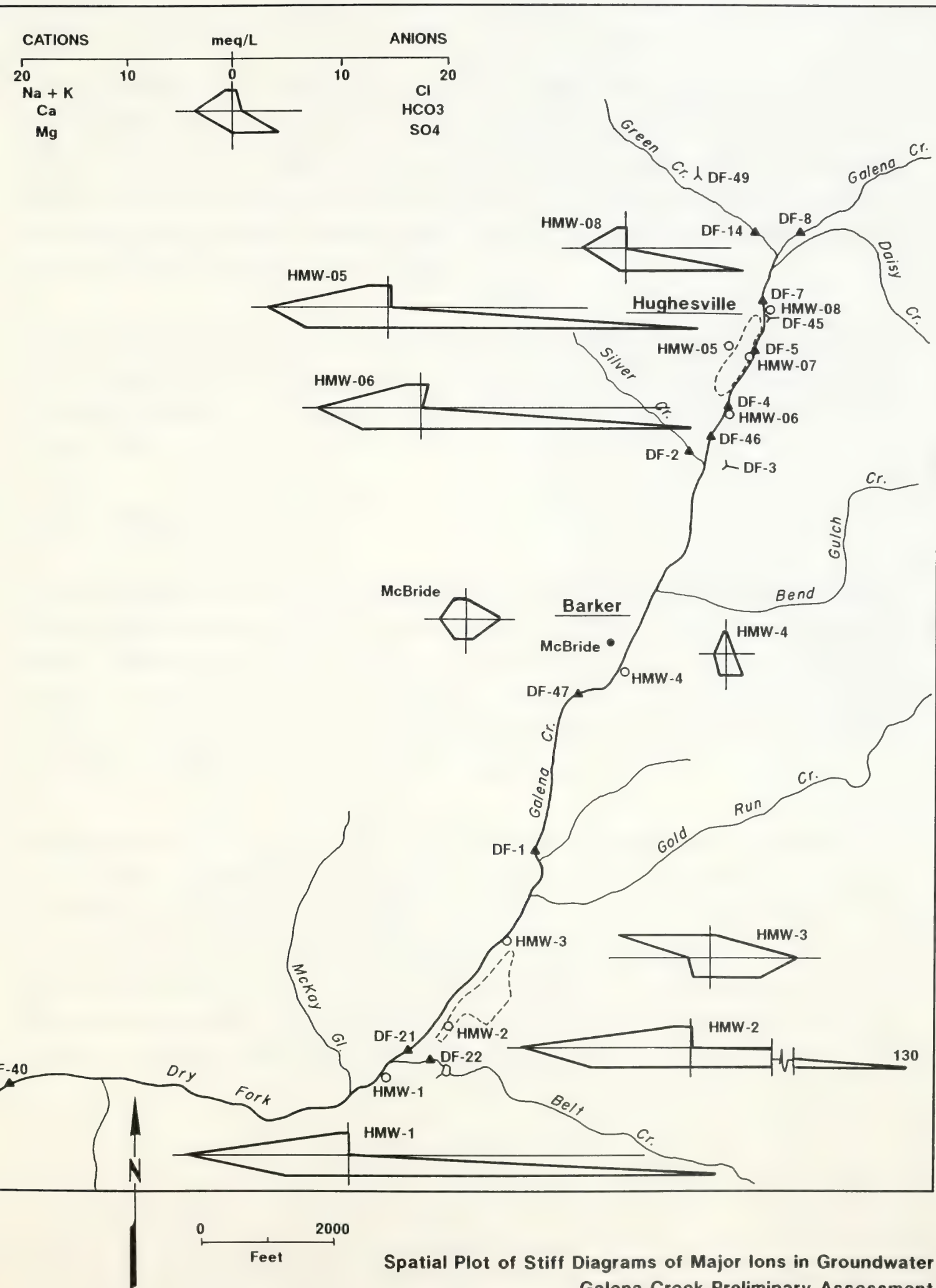
In this section, we present and interpret groundwater quality data collected during the PA. The groundwater quality data base resulting from the PA is contained in Appendix B-2.

4.3.2.1 Common Ions

Figure 4-3 is a trilinear diagram showing relative concentrations of major ions measured at the nine wells sampled during this PA. Figure 4-4 shows stiff diagrams of major ions



Trilinear Diagram of Major Ions in Groundwater
Galena Creek Preliminary Assessment
FIGURE 4-3



Spatial Plot of Stiff Diagrams of Major Ions in Groundwater
Galena Creek Preliminary Assessment

FIGURE 4-4

spatially for these same data sets. Our review of these figures shows that monitoring wells HMW-3 and the McBride well intercept water dissimilar to other wells sampled. Water in well HMW-3 exhibited a sodium bicarbonate type water. The relatively high sodium concentration detected in water from this well is probably caused by reaction of well water with granular bentonite used to backfill the borehole. The McBride well contained a calcium bicarbonate type water.

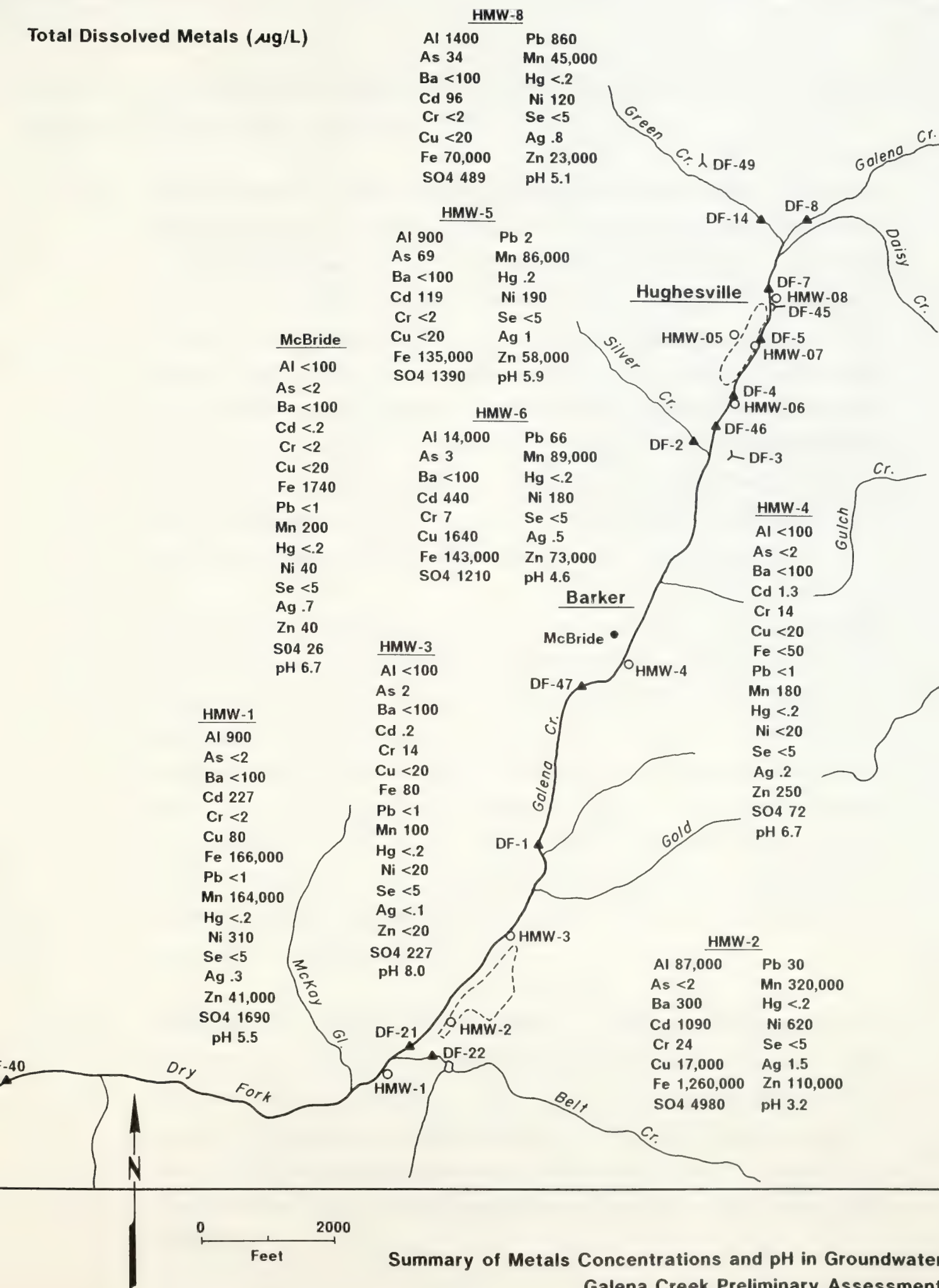
All other wells sampled during the PA exhibited calcium sulfate type water. These wells are all located proximal to mine wastes. The predominance of sulfate in groundwater at these sites is typified by stiff diagrams for wells HMW-1, HMW-2, HMW-5, and HMW-6 (Figure 4-4).

4.3.2.2 Metals and pH

Figure 4-5 summarizes dissolved metals, sulfate concentrations, and pH values measured in groundwater samples collected from wells in the study site. These data indicate pH values measured in the groundwater samples are relatively good indicators of dissolved metals concentrations. Samples collected from wells HMW-6 and HMW-2 exhibited pH values of 4.6 and 3.2, respectively. Samples from both these wells contained relatively high concentrations of dissolved cadmium, copper, lead, and zinc.

Samples collected from wells HMW-4, HMW-3, and the McBride well had pH values of 6.7, 8.0, and 7.3, respectively (Figure 4-5). In general, dissolved metals concentrations in samples collected from these wells were relatively low. Acidic groundwater was generally encountered by wells completed proximal to or downgradient of mine waste areas (wells HMW-1, HMW-2, HMW-5, HMW-6, and HMW-8). Wells intercepting neutral pH water are generally located either upgradient of mine waste areas or are completed in limestone bedrock (HMW-3, HMW-4, and McBride).

Total Dissolved Metals ($\mu\text{g/L}$)



Based on a review of laboratory analyses completed on groundwater samples collected during the PA, the following trends are evident:

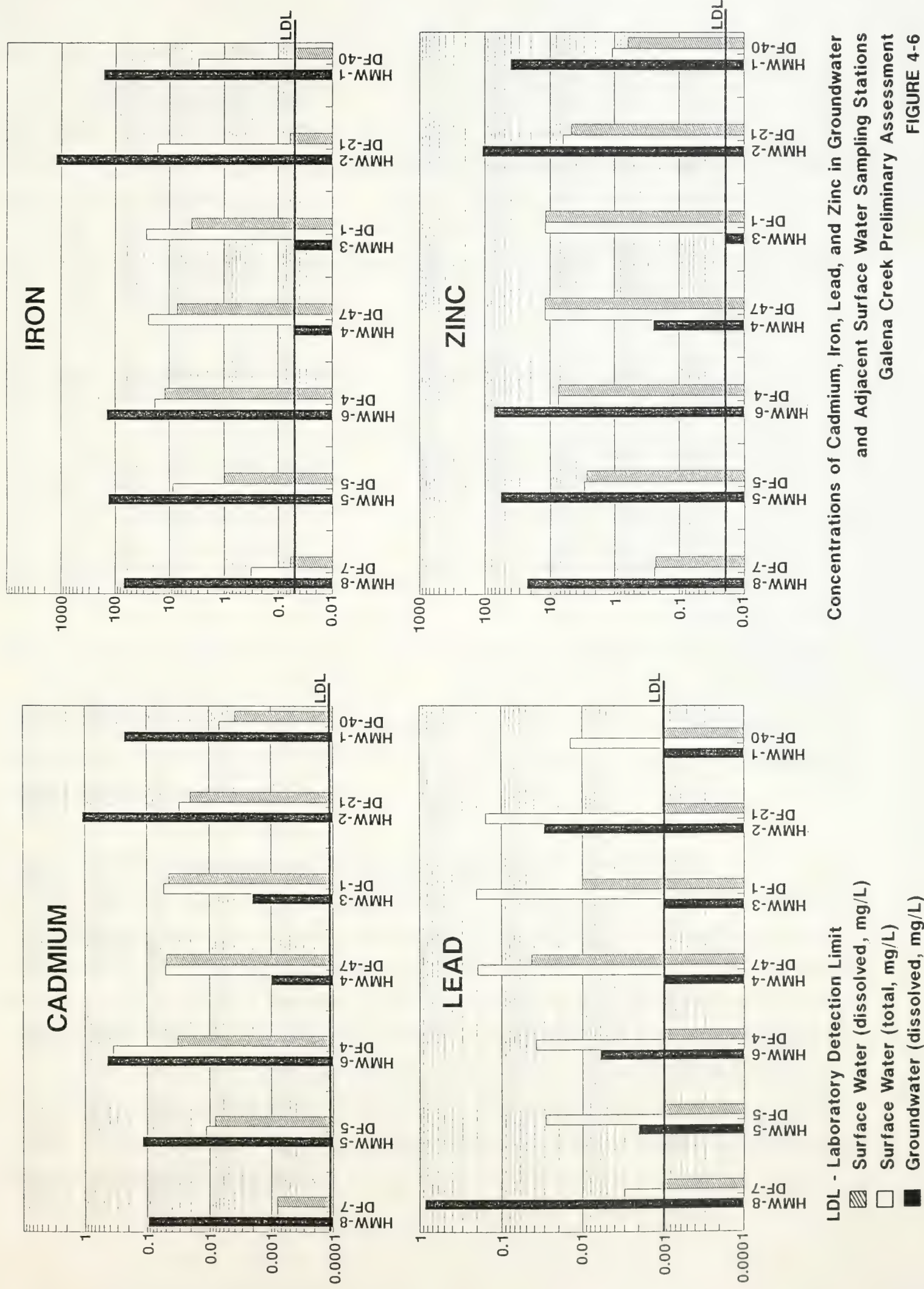
- ◆ Dissolved arsenic and lead concentrations are highest in wells located near the Block P dump. Samples from wells HMW-5 and HMW-8 (Figure 4-5) contained dissolved arsenic concentrations of 69 and 34 $\mu\text{g/L}$, respectively. All other groundwater samples contained arsenic concentrations at or below the laboratory detection limit of 2 $\mu\text{g/L}$. Dissolved lead concentrations were highest in samples collected from wells HMW-8 and HMW-6 at 860 and 66 $\mu\text{g/L}$, respectively (Figure 4-5). With the exception of well HMW-2, located immediately downgradient of the Block P tailings, all other samples collected during this study exhibited dissolved lead concentrations near or below the laboratory detection limit of 1 $\mu\text{g/L}$. A dissolved lead concentration of 30 $\mu\text{g/L}$ was measured in the sample collected from well HMW-2.
- ◆ Relatively high dissolved cadmium, copper, and zinc concentrations were measured in samples collected from wells located proximal to the Block P mine dump and downgradient from the Block P Mill tailings (Figure 4-5). The highest dissolved cadmium concentrations were measured in the sample collected from well HMW-2, located immediately downgradient of the Block P Mill tailings. This sample contained a dissolved cadmium concentration of 1,090 $\mu\text{g/L}$. The highest dissolved copper and zinc concentrations were measured in samples collected from wells HMW-2 and HMW-6, located immediately downgradient of the Block P Mill tailings and mine dump, respectively.
- ◆ Dissolved iron concentrations measured in shallow groundwater tend to increase from above to immediately below the Block P Mine dump. Dissolved iron concentrations in groundwater adjacent to Galena Creek appear to measurably decrease between the Block P Mine dump and the Block P Mill tailings (wells HMW-4 and HMW-3; Figure 4-5). Dissolved iron concentrations then increase in wells located below the Block P Mill tailings (HMW-2).

- ◆ The upgradient extent of metals impacted groundwater proximal to the Block P Mine dump was not determined during this PA. Monitoring well HMW-8 (Figure 4-1) was installed near the upper end of the Block P Mine dump to evaluate groundwater quality adjacent to Galena Creek as it enters the mine area. Relatively high concentrations of dissolved arsenic, cadmium, iron, lead, manganese, and zinc in groundwater sampled at this location indicate a source of metals is located further upgradient than well HMW-8.

Comparative plots of cadmium, iron, lead, and zinc concentrations in monitoring wells and adjacent surface water sampling stations are presented in Figure 4-6. Two areas which exhibit relatively poor quality groundwater are evident on Figure 4-6. These areas are the Block P Mine dump (near wells HMW-5 and HMW-6) and the Block P Mill tailings (near well HMW-2). Impacts to surface water resulting from inflow of metals-laden groundwater are realized primarily in the vicinity of the Block P Mine dump (Figure 4-6). The metals plume identified in the groundwater south of the Block P Mill tailings (well HMW-2) does not appear to affect surface water quality near the mouth of Galena Creek (Station DF-21, Figure 4-6). Concentrations of dissolved metals in the shallow groundwater system are relatively low from near Barker (well HMW-4, Figure 4-6), to immediately upgradient of the Block P mill tailings (well HMW-3, Figure 4-6).

Based on dissolved metals concentrations measured in samples collected from monitoring well HMW-1 (Figure 4-5), it appears that a component of metals-laden groundwater is migrating south from the Block P Mill tailings and is flowing beneath the Dry Fork of Belt Creek. The plume appears to be relatively unaffected by dilution or attenuation of water in the Dry Fork of Belt Creek.

Groundwater impacts to the Dry Fork of Belt Creek are visible just above the streamline in the reach above the mouth of Galena Creek. Iron-stained cobbles and gravel are evident at this location which are indicative of seepage of metals-laden water into the Dry Fork.



Concentrations of Cadmium, Iron, Lead, and Zinc in Groundwater and Adjacent Surface Water Sampling Stations
Galena Creek Preliminary Assessment
FIGURE 4-6

4.3.3 Groundwater Occurrence

In general, groundwater is probably present in the Galena Creek drainage in five different water-bearing systems:

- ◆ Coarse-grained alluvial sediments associated with Galena Creek and the Dry Fork of Belt Creek;
- ◆ Unfractured sedimentary and igneous rock;
- ◆ Fractured sedimentary and igneous rock;
- ◆ Mill tailings and
- ◆ Underground mine workings.

Monitoring wells installed during this PA encountered groundwater in alluvial sediments, unfractured sedimentary and igneous rock, and fractured igneous rock. Monitoring wells were not installed in the Block P mill tailings during this PA but a portion of this deposit is anticipated to be saturated. Further, none of the installed monitoring wells intercepted underground mine workings.

Alluvial sediments are present along certain reaches of Galena Creek. Because the stream is flowing in a relatively high energy environment, an extensive alluvial system has not developed. Based on borehole data collected during this PA, the thickest deposits of alluvial sediments were encountered along Galena Creek near Barker (HMW-4, Figure 4-1) and along the Dry Fork of Belt Creek downstream from its confluence with Galena Creek (HMW-1, Figure 4-1). Alluvial sediments at these locations were approximately 11 feet thick. Depending on local groundwater flow regimes, these alluvial sediments may be recharged with water from the stream or with groundwater inflow from bedrock systems. The alluvial sediments probably discharge water to Galena Creek where bedrock subcrops to the creek.

The occurrence of groundwater and the rate of groundwater movement in massive sedimentary and igneous bedrock systems in the area is primarily controlled by the primary permeability of the rock mass. Slug test data collected during this PA indicate that unfractured rock units in the Galena Creek drainage exhibit low hydraulic conductivities (see Section 4.3.5) and therefore, are not expected to yield significant quantities of water to wells. Further, massive rock units throughout the study area are not expected to supply a significant source of groundwater recharge to adjacent alluvial and surface water systems.

Groundwater occurrence and movement in fractured bedrock systems is primarily controlled by secondary permeability associated with the joints and fractures in the rock mass. Characterizing the groundwater environment in these types of systems is nearly impossible because of the complexities of the flow paths in the unit. Data were not collected during this investigation to determine the locations and extent of fractured bedrock in the district. However, we suspect that one of the primary avenues of groundwater recharge to alluvial sediments along Galena Creek and to Galena Creek itself is fractured bedrock.

We did not encounter saturated mill tailings with any boreholes drilled during this PA. However, the presence of several small seeps along the eastern edge of the upper impoundment of the Block P Mill tailings suggests that at least a portion of this deposit is saturated. Mill tailings typically exhibit relatively low hydraulic conductivities, and therefore, tend to retain water for a considerable length of time. Snowmelt and precipitation events and localized springs are probably the primary sources of recharge to these tailings.

Underground mine workings were not directly characterized during this investigation. However, water quality and flow data were obtained at adit discharges at the Queen of the Hills, Danny T, and Carter mine openings (see Section 3.0). This information provides some indication of groundwater characteristics in the underground workings in the district. These underground mine workings likely intercept a multitude of fracture zones in the area and consequently accelerate the transfer of water to nearby surface water systems.

Underground mine workings near the Block P Mine dump are likely the primary source of acid mine discharge to Galena Creek. Hydraulic characteristics of these workings were not directly evaluated during this investigation. The impact of the underground workings on Galena Creek is evident by the presence of a spring near some mine cars at the southern end of the Block P Mine dump and the measured degradation of Galena Creek water quality in this reach of stream during baseflow conditions.

4.3.4 Groundwater Movement

Depths to groundwater measured in monitoring wells are presented in Table 4-2. In addition, the relative elevation of groundwater in each well as compared to stream stage elevations in Galena Creek in reaches adjacent to the wells are summarized in Table 4-2. These data indicate the average stream gradient of Galena Creek in the reach adjacent to the Block P Mine dump is approximately 5%.

The Galena Creek channel flattens slightly below the Block P Mine dump but still maintains a relatively steep gradient throughout the study area. The relatively steep gradient of the Galena Creek channel makes it difficult to directly evaluate the influent/effluent characteristics of Galena Creek by comparing surface water elevations with a single groundwater elevation adjacent to the creek. However, general relationships between surface water and groundwater systems within the study area are evident from the data contained in Table 4-2 on the following page.

- ◆ Groundwater is moving into Galena Creek in the area along the Block P Mine dump. The elevation of groundwater in monitoring well HMW-5, located on top of the dump, is approximately 18 feet higher than the stage in Galena Creek as measured perpendicular to the valley axis from well HMW-5 (Table 4-2). Other evidence of groundwater inflow to Galena Creek along the Block P Mine dump includes the presence of a relatively large spring (DNRC's mine car spring) located near the lower end of the dump and the presence of seepage faces along the west side of the Galena Creek channel.

TABLE 4-2**SUMMARY OF GROUNDWATER LEVEL MEASUREMENTS AND SURVEY DATA
GALENA CREEK PRELIMINARY ASSESSMENT**

LOCATION	DEPTH TO GROUNDWATER⁽¹⁾	RELATIVE WATER ELEVATION⁽²⁾
HMW-1	4.15	972.39
DRY FORK BELT CREEK	-	972.36
HMW-2	6.51	993.49
GALENA CREEK	-	995.65
HMW-3	16.46	983.54
GALENA CREEK	-	989.81
HMW-4	4.22	995.78
GALENA CREEK	-	991.95
HMW-5	85.42	1059.80
GALENA CREEK	-	1041.83
HMW-6	5.30	997.67
GALENA CREEK	-	999.34
HMW-8	8.12	1064.74
GALENA CREEK	-	1071.29

Notes: (1) Depth to groundwater reported in feet below measuring point.

(2) Surface water elevations surveyed to nearest point perpendicular to the adjacent monitoring well.

- ◆ Groundwater movement into Galena Creek is evident in the area near Barker (well HMW-4; Figure 4-1; Table 4-2).
- ◆ The stage in Galena Creek in the vicinity of the Block P Mill tailings is higher than groundwater elevations measured in monitoring wells HMW-2 and HMW-3 (Figure 4-1, Table 4-2). These data suggest Galena Creek is losing water to the adjacent groundwater system in this reach of the stream. The premise that Galena Creek is losing water at this location is supported by surface water and groundwater quality data collected at stations adjacent to the Block P Mill tailings. Concentrations of dissolved cadmium, copper, iron, and zinc measured in samples collected from monitoring well HMW-2 (located downgradient of the Block P Mill tailings) are relatively high as compared to other groundwater sampled in the study area (Figure 4-5). However, surface water data for the reach of Galena Creek adjacent to the tailings deposit (Figures 3-12 through 3-23) do not indicate a corresponding increase in metals concentrations or loading.

Survey data collected at wells HMW-1, HMW-6, and HMW-8 are not sufficient to conclusively determine the influent/effluent characteristics of Galena Creek at these locations.

4.3.5 Aquifer Testing

Computer generated plots of slug-test data and associated hydraulic conductivity values are contained in Appendix B-3. Table 4-3 summarizes slug-test data collected during this PA.

Slug tests completed during this PA provided hydraulic conductivity values for alluvial sediments, unfractured bedrock, and weathered bedrock (Table 4-3). The calculated hydraulic conductivity of well HMW-4 (completed in alluvium) was approximately 18 feet/day. This hydraulic conductivity value is suspected to be relatively low for typical alluvial sediments within the study area. We suspect the majority of alluvial sediments

TABLE 4-3
SUMMARY OF SLUG-TEST DATA AND ASSOCIATED HYDRAULIC CONDUCTIVITY
VALUES; GALENA CREEK PRELIMINARY ASSESSMENT

WELL NUMBER	WATER BEARING MATERIAL	HYDRAULIC CONDUCTIVITY*
HMW-4	Alluvium	18 feet/day
HMW-5	Syenite	0.04 feet/day
HMW-6	Syenite	1.5 feet/day
HMW-8	Weathered Syenite	7.8 feet/day

* Hydraulic conductivity values calculated using Bouwer and Rice, 1976.

within the Galena Creek and Dry Fork of Belt Creek drainages exhibit considerably higher hydraulic conductivity values than that calculated from slug testing well HMW-4.

Monitoring well HMW-5 (Figure 4-1) was completed in a massive igneous rock unit beneath the Block P Mine dump. The hydraulic conductivity calculated from slug test data collected at well HMW-5 was 0.04 feet/day (Table 4-3). This value is typical of massive igneous rock with few interconnected fractures or joints (Freeze and Cherry, 1979). Low permeability massive bedrock of this type is not expected to transmit a significant quantity of groundwater.

Hydraulic conductivity values for fractured bedrock were obtained from slug tests completed in wells HMW-6 and HMW-8. These values ranged from 1.5 to 7.8 feet/day (Table 4-3). Fractured rock with this range of hydraulic conductivity, coupled to underground mine workings, is expected to transmit the majority of groundwater near the Block P Mine dump.

Slug test data for wells HMW-1, HMW-2, and HMW-3 are not included in Appendix B-3 or Table 4-3. The relatively high permeability of alluvial sediments adjacent to completion intervals in wells HMW-1 and HMW-2 (Figure 4-1) prevented accurate data collection at these sites. Water levels recovered in these wells within several seconds after introduction of the slug. Our experience has been that slug tests are not applicable for wells completed in material with hydraulic conductivities greater than about 50 feet/day. Hydrogeologist's observations of subsurface material and return water encountered while drilling wells HMW-1 and HMW-2 indicate the alluvial sediments at these locations probably have hydraulic conductivity values ranging from 1,000 to 10,000 feet/day. These values are typical for coarse-grained alluvial sand and gravel (Freeze and Cherry, 1979).

Monitoring well HMW-1 (Figure 4-1) is completed in competent Cambrian Pilgrim Formation limestone. The water level did not measurably decline in this well after the slug was introduced into the borehole for a period of approximately one hour. Well HMW-1 is likely completed in relatively unfractured limestone which has a very low primary permeability. We suspect the hydraulic conductivity of this unfractured limestone ranges from approximately 10^{-3} to 10^{-5} feet/day.

Hydraulic conductivity data collected during this investigation may be used to calculate groundwater flux through various groundwater systems within the study area. Such analyses will be completed, if necessary, to support analyses of reclamation alternatives for various portions of the site.

5.0 SOILS/MINE WASTE INVESTIGATION

The purpose of the soil/mine waste sampling program was to characterize the magnitude of metals enrichment in mine and mill waste materials and streamside tailings materials within the project study area. The primary objective of the sampling program was to collect a representative number of samples from the various mine waste sources in the study area to determine the relative importance of each with respect to environmental impacts. The following section describes the methods used to achieve objectives outlined in the project sampling and analysis plan (Chen-Northern, 1990b). We also describe changes to the sampling and analysis plan resulting from completion of the soils/mine waste investigation and we present data and results is provided.

5.1 METHODS

The procedures followed to complete the soil/mine waste investigation were consistent with methods outlined in the project sampling and analysis plan (Chen-Northern, 1990b). A brief description of methods is provided in this subsection. More detailed descriptions of study methods are contained in the project sampling and analysis plan.

5.1.1 Soil/Mine Waste Sample Site Selection

Chen-Northern's field sampling team collected soil/mine waste samples from three types of mining/milling wastes. For purposes of this PA, the soil/mine waste material on-site was categorized into waste rock dump material, mill tailings, and streamside tailings. A limited number of samples of native soils underlying waste materials were also collected to evaluate the potential for vertical migration of contaminants.

Soil/mine waste sampling locations were selected to provide a representative cross-section of material from potential contaminant source materials in the study area. Sampling locations and the number of samples collected at each site are summarized in Table 5-1. Sample site locations are shown on Figure 5-1.

TABLE 5-1
SUMMARY OF SOIL AND MINE WASTE SAMPLE LOCATIONS
GALENA CREEK PRELIMINARY ASSESSMENT

Location	No. of Sample Sites	Location	No. of Sample Sites
Block P Mill Tailings	6	Marcelline	3
Block P Dump	11	Liberty	3
Wright/Edwards Dump	5	Carter	2
Danny T	2	Bender Creek SST	5
Belt SST ¹	1	Barker SST	2
Native ²	4		

1 SST = Streamside Tailings

2 Native soil sample collected from below various waste material locations.

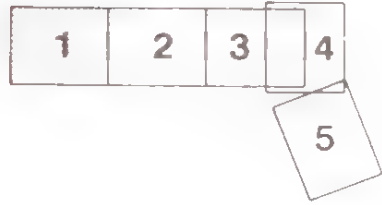
Waste rock dump material was collected from six of the larger waste dumps for a total of 24 sample sites. These six mine waste dumps were chosen because they represented a large proportion of the total amount of mine waste in the district and were regarded as having the greatest potential for impacting surface and groundwater in the project area. Of the 24 sample sites, 16 sample sites were located on the Block P Mine dump and the Wright and Edwards dumps, two of the largest waste rock dumps in the district (Figure 5-1).

Mill tailings samples were collected from six sites located on the Block P Mill tailings ponds (Figure 5-1). Three sample sites were located on the lower pond and three sites on the upper pond.

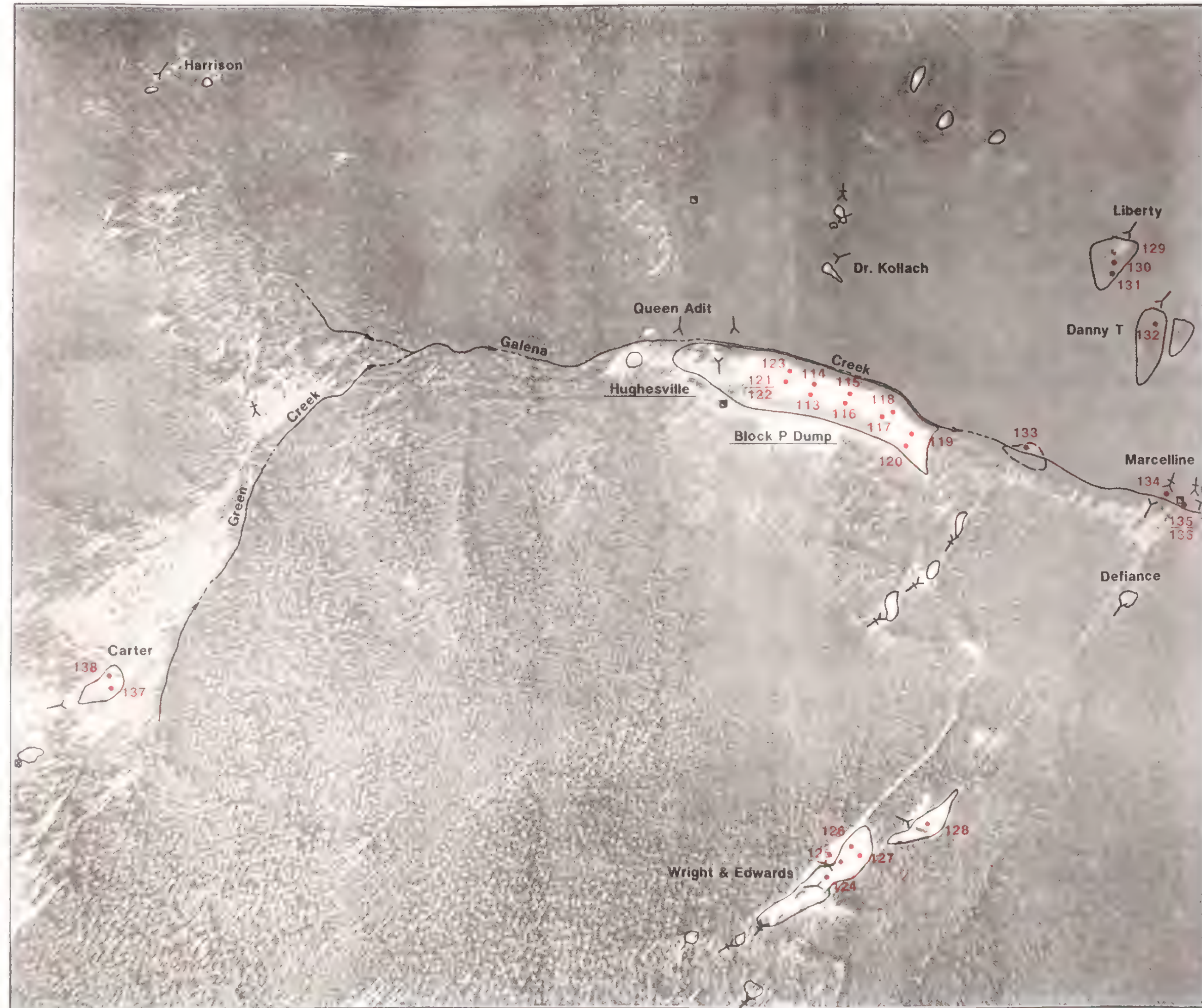
Samples of streamside tailings material were collected from three different tailings deposition areas on both Galena Creek and the Dry Fork of Belt Creek. The largest of these tailing deposits, the Bender Creek tailings (Figure 5-1), is believed to have been



Approx. 500 Feet



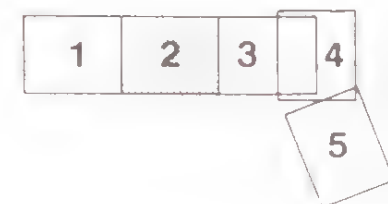
-  Adit
-  Caved Adit
-  Shaft
-  Caved Shaft
-  Waste Rock Dump
-  Streamside Tailings
-  Soils/Mine Waste Sample Site



Soils/Mine Waste Sample Sites
Galena Creek Preliminary Assessment
FIGURE 5-1 (sheet 1 of 5)



Approx. 500 Feet



- Adit
- Caved Adit
- Shaft
- Caved Shaft
- Waste Rock Dump
- Streamside Tailings
- Soils, Mine Waste Sample Site

FIGURE 5-1 (sheet 2 of 5)

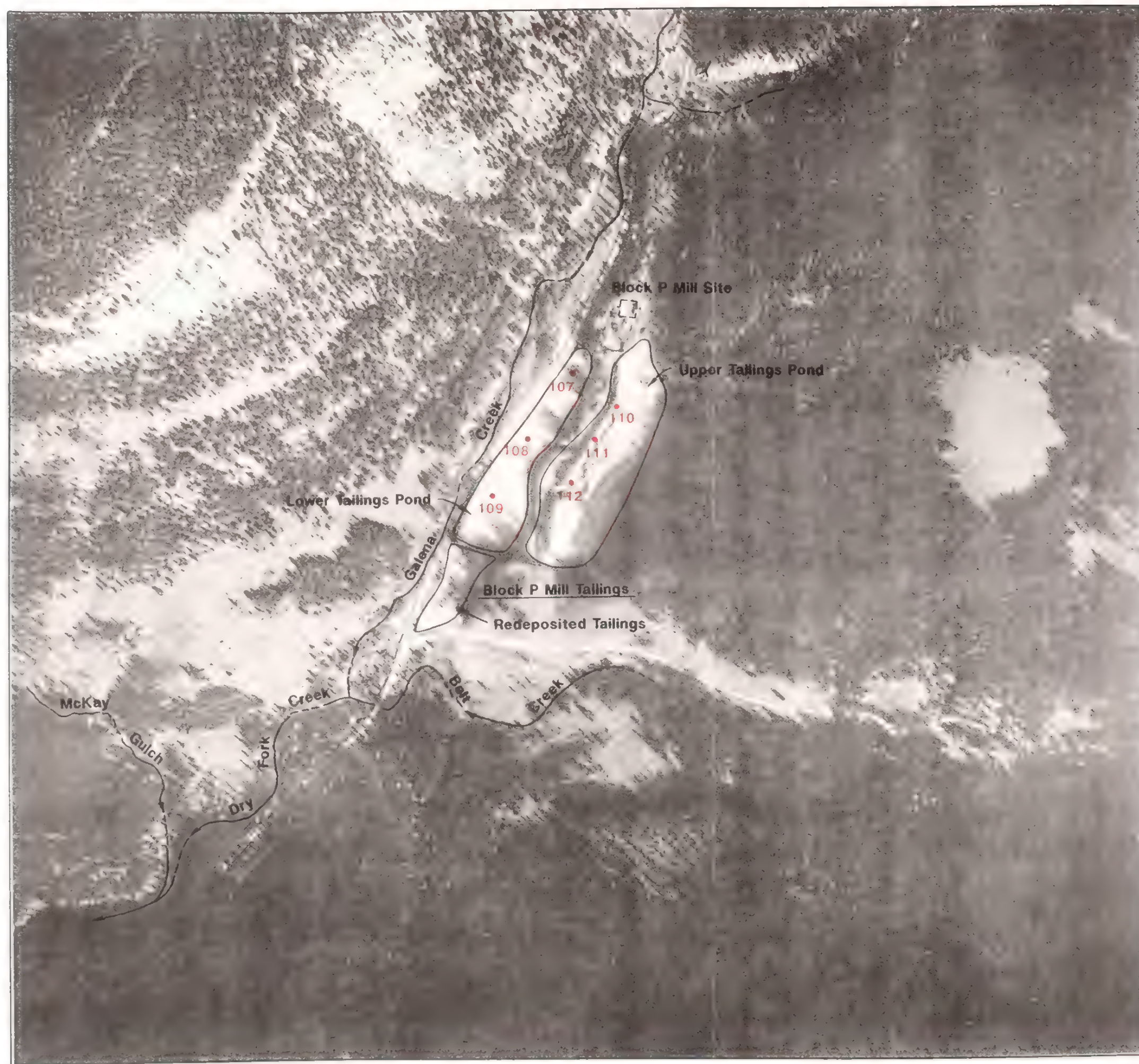


Approx. 500 Feet



- Adit
- Caved Adit
- Shaft
- Caved Shaft
- Waste Rock Dump
- Streamside Tailings
- Soils Mine Waste Sample Site

FIGURE 5-1 (sheet 3 of 5)



Approx. 500 Feet



- Adit
- Caved Adit
- Shaft
- Caved Shaft
- Waste Rock Dump
- Streamside Tailings
- Sample Site

FIGURE 5-1 (sheet 4 of 5)

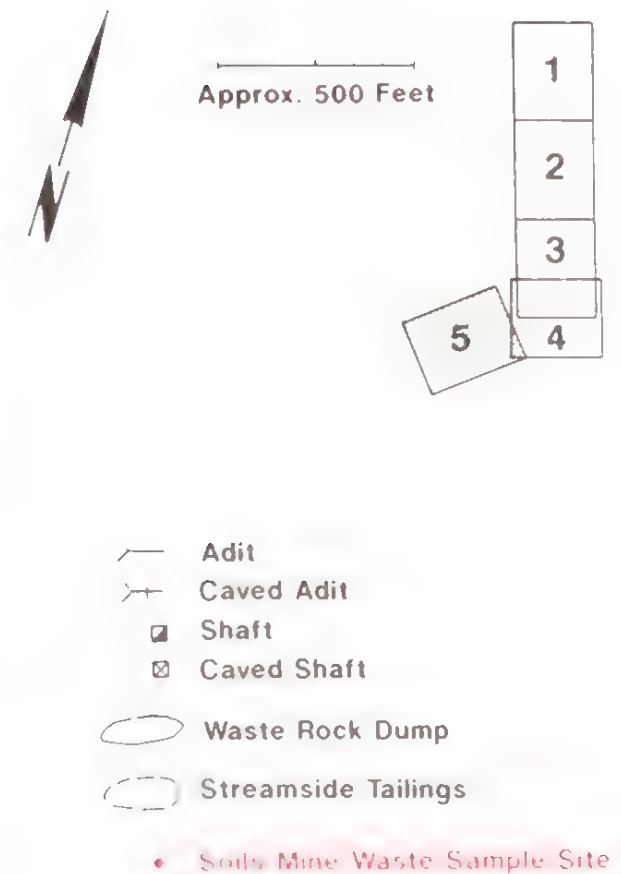


FIGURE 5-1 (sheet 5 of 5)

deposited by floods carrying material from the Block P tailings ponds (Ms. Gwen McBride, personnel communication, December 6, 1990). It is also probable that some of the Bender Creek streamside tailings originated from other sources on the Galena Creek drainage.

Smaller streamside tailings deposits are distributed along Galena Creek from the Block P Mine dump downstream to the Block P Mill tailings (Figure 5-1). Most of these deposits are areally small and are generally thin. Three of these scattered deposits were sampled during this PA. These included a site on the Belt Patent and one site above and one site below the confluence of Bend Gulch and Galena Creek (designated as the Barker streamside tailings in Table 5-1) (Figure 5-1).

A limited number of samples of native soils underlying waste materials was collected from sites where depth to native soil was within reach of hand augering or hand troweling sampling methods. The locations of these native soil sampling sites included an area below the Bender Creek streamside tailings, an area of streamside tailings downstream of the Barker townsite, the Marcelline waste rock dump, and the upper Block P Mill tailings pond (Figure 5-1).

5.1.2 Soil/Mine Waste Sampling

Field sampling crews collected almost all soil/mine waste material with bucket augers and hand trowels. The field sampling crew also collected samples from sample site HMW-5 using a split spoon sampler during the drilling of monitoring well HMW-5. All sampling and decontamination procedures were conducted in accordance with procedures specified in the project sampling and analysis plan (Chen-Northern, 1990b).

Samples were collected from one to four depth increments at each sample site. The number of intervals sampled varied from site to site and was generally based on field sampling crew observations of changes in lithology, depth of auger refusal, and specific intervals of interest based on objectives specified in Section 5.1. In general, the sampled vertical intervals included a surface sample (0 to 1 inch), a near-surface interval (1 inch

to approximately 24 to 36 inches), a moderately deep interval (approximately 36 inches to approximately 66 to 78 inches), and a relatively deep zone (greater than approximately 66 inches).

Soil/mine waste samples were collected in heavy-duty polyethylene resealable bags. Approximately one gallon of sample was collected from each depth interval. Samples were placed in coolers and transported to Chen-Northern's Helena office for preparation before shipment to the analytical laboratory.

Field quality assurance/quality control (QA/QC) samples incorporated into the sample train included field duplicates and blind field standards. As outlined in the sampling and analysis plan, no cross-contamination blanks were prepared because of the relatively low possibility of cross-contaminating soil material samples. A more detailed discussion of QA/QC procedures is contained in the project sampling and analysis plan (Chen-Northern, 1990b).

5.1.3 Sample Selection Process For Laboratory Analysis

Soil/mine waste samples were subjected to two types of analytical methods to determine physicochemical properties. The two methods used were laboratory analytical procedures and X-ray fluorescence (XRF) spectrometry. A subset of the total number of samples collected were submitted to the laboratory for wet chemical analytical determinations and the entire set of samples were screened for total metal concentrations using a portable XRF instrument.

Wet chemistry methods were used to determine total metal concentrations, saturated paste extract metal concentrations, sulfur fractionation, texture, pH, electrical conductivity (EC), and saturation percent. Parameters analyzed, analytical methods used, and detection limits are summarized in Table 5-2.

Chen-Northern's project soil scientist selected a representative number of samples from each of the four sample categories (mine waste, mill tailings, streamside tailings, and native soil) for laboratory analysis. A total of 21 waste rock samples, nine mill tailings

TABLE 5-2
SOIL AND MINE WASTE ANALYTICAL METHODS
AND REQUIRED DETECTION LIMITS
GALENA CREEK PRELIMINARY ASSESSMENT

Analyte ⁽¹⁾	Method ⁽²⁾	Detection Limit (mg/kg)
Aluminum	EPA 6010	40
Arsenic	EPA 7060/7061	2
Cadmium	EPA 6010	1
Chromium	EPA 6010	2
Copper	EPA 6010	5
Iron	EPA 6010	20
Lead	EPA 6010	1
Manganese	EPA 7471	3
Mercury	EPA 6010	0.04
Nickel	EPA 6010	8
Silver	EPA 6010	2
Zinc	EPA 6010	4
Sulfur Fractionation	ASTM D24920-84	
Texture	ASA 43-5	---
pH	USDA 21A	---
Electrical Conductivity	USDA 4B	---

(1) Samples selectively analyzed for total and saturated paste extract metals.

(2) EPA, 1979 (revised 1983). Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. Environmental Monitoring and Support Laboratory, U.S. EPA, Cincinnati, Ohio.

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American Society of Agronomy, 1965. Standard Methods of Soil Analysis. Monograph No. 9. C.A. Black, ed. Madison, Wisconsin.

USDA, 1969. Diagnosis and Improvement of Saline and Alkali Soils, Agricultural Handbook No. 60. L.A. Richards, ed. U.S. Government Printing Office, Washington D.C.

samples, nine streamside tailings samples, and four native soil samples were submitted to Chen-Northern's Billings laboratory for analysis. Of these procedures, 40 total metal, 25 saturated paste extract metal, 13 sulfur fractionation, 31 texture, and 45 pH, EC, and saturation percent determinations were made. All samples collected were analyzed with the XRF for total metal concentrations.

5.1.4 XRF Analysis

Chen-Northern soils scientists used an ATX Model 100 XRF spectrometer instrument to determine total metal concentrations in the 45 samples which were not submitted to the laboratory. The XRF instrument was used primarily to obtain an estimate of total metal concentrations in these samples. Total metal concentrations in the 40 samples submitted to the laboratory were used as calibration standards for XRF analysis.

The ATX-100 utilizes two different radioactive sources for quantification of up to 95 different elements. The XRF, however, is highly sensitive to sample matrix interferences, and is practically limited to measurement of only relatively high concentrations of particular elements in a specific type of material. Output produced by the ATX-100 includes a spectral curve which graphically shows the number of counts produced at each spectral wavelength, the element which emits X-rays at each particular wavelength, and an index number which is a number representing the number of counts received in a spectral band for a particular element.

The ATX-100 was calibrated using laboratory determined total metal concentrations as calibration standards. This method of calibration provides the best estimate of total metals because matrix interferences are minimized and both sets of samples (i.e. the 'knowns' and 'unknowns') are generally composed of comparable metals.

Our review of laboratory analytical data indicated that cadmium, chromium, mercury, and silver total metal concentrations were too low for adequate estimation by the XRF. Although the XRF automatically computes index values for these metals, we selected seven metals which we felt the XRF provided estimates with a satisfactory level of confidence. These estimates included arsenic, copper, iron, manganese, nickel, lead, and zinc. All of these elements emitted X-rays when exposed to a cadmium-109 source.

Total metal concentrations from 40 samples were used as calibration standards. Index values computed by XRF analyses were correlated with corresponding total metal concentrations determined by the laboratory. A multiple regression statistical procedure was used to determine a 'best-fit' equation for the conversion of XRF index values to total metal concentrations. Regression correlation coefficients (r^2) of greater than 0.75 were determined for all the selected metals except manganese. Manganese X-ray emissions were substantially obscured by interferences from iron emissions. This result effectively eliminated estimates of manganese for the 45 unknown samples but allowed good estimates for arsenic, copper, iron, nickel, lead, and zinc. Calculations and statistics used for XRF calibration are contained in Appendix C-1.

All soil/mine waste samples analyzed by the XRF were prepared in the same manner as laboratory samples analyzed for total metals. This procedure was followed to minimize matrix interferences due to differences in grain size or moisture content. Sample preparation included oven drying, grinding in a porcelain plate soil grinder, and pulverizing with a mortar and pestle to a fine powder with a grain size generally less than 60 mesh.

A Chen-Northern technician used several calibration and QA/QC procedures to ensure accurate sample measurements were obtained. These procedures included use of internal calibration standards, solid matrix standards, replicate measurements, lab-determined concentrations, and field duplicates. Internal calibration standards were measured three times per day to confirm instrument accuracy. Measurements of the solid matrix standards and sample replicates were made every ten samples. If measurements of either the solid matrix standards or replicate measurement were greater than 10% above or below the designated mean for either sample, measurements of the previous 10 samples were flagged as estimates.

5.2 CHANGES TO THE SAMPLING AND ANALYSIS PLAN

Several minor changes were made to the project sampling and analysis plan (Chen-Northern, 1990b) as a result of completing the soils/mine waste work task. None of these changes affected the overall purpose, scope of work, or data quality objectives set

forth in the plan. All methods and procedures specified in the project sampling and analysis plan were followed.

Specific changes which occurred included the need to adjust the number of samples collected at each sampling site (Table 5-1) and the depths at which samples were collected. Sampled depth intervals were adjusted to correlate with lithologic changes observed at specific samples sites instead of predetermined depth intervals specified in the sample and analysis plan. Also, certain depth intervals were not collected at some sample sites if an interval was already well represented (e.g. surface interval at the Block P Mine dump sample sites).

5.3 PRESENTATION OF DATA AND RESULTS

All soil/mine waste samples were grouped into four categories to facilitate data analysis. The four groups included waste rock, mill tailings, streamside tailings, and native soil. A discussion of the physical and chemical properties of each of the four groups is presented below.

5.3.1 Waste Rock

A total of 42 waste rock samples were collected from six of the larger waste rock dumps in the Galena Creek drainage. All 42 samples were analyzed for total metal concentrations with the XRF. A subset of 18 representative samples of the material were submitted to the laboratory for analysis of total metal concentrations. Ten samples were analyzed by the laboratory for saturated paste extract metal concentrations.

All the waste rock dumps sampled are composed of similar waste materials. These materials are primarily coarse fragments consisting of quartz monzonite, syenite, and silver/lead ore in a matrix of yellow-brown, red-brown, tan, and gray sandy loam to loamy sand material. Waste dump materials did not substantially vary in appearance with depth to the deepest hand sampled depth of 48 inches.

Mean values for pH, EC, and saturation percent metals concentrations are presented in Table 5-3 for the 18 waste rock dump samples submitted to the laboratory. Mean saturated paste extract pH for waste rock dump material was relatively acidic at 2.4 standard units. Electrical conductivity (EC) of the samples averaged 4.4 mmhos/cm. Such a value indicates a moderate concentration of soluble elements is present in the paste extract. Saturation averaged 29%, indicating the material contains a moderate amount of water holding capacity.

TABLE 5-3
MEAN WASTE ROCK PHYSICAL CHARACTERISTICS
GALENA CREEK PRELIMINARY ASSESSMENT

Parameter	Unit	Mean ¹	Standard Deviation	Minimum	Maximum
pH	standard	2.4	1.0	1.6	5.3
EC	mmhos/cm	4.4	3.0	0.2	11.5
Saturation	%	29	4	24	38

¹ Summary statistics based on 18 samples.

Table 5-4 summarizes laboratory determined total metal and saturated paste extract metal concentrations present in waste rock material. Notable total metal concentrations include relatively high concentrations of arsenic, copper, iron, lead, and zinc compared to national averages. Manganese concentrations are also high but this is primarily a result of high manganese concentrations measured in two samples.

TABLE 5-4
AVERAGE CONCENTRATIONS OF TOTAL AND EXTRACTABLE METALS
IN WASTE ROCK
GALENA CREEK PRELIMINARY ASSESSMENT

Parameter	Type ¹	Mean	Standard Deviation	Minimum	Maximum
Aluminum	Total	2,730.0	849.0	1,750.0	4,400.0
	Extract	31.2	25.83	0.40	74.1
Arsenic	Total	416.0	186.0	116.0	840.0
	Extract	0.145	0.154	0.01	0.425
Cadmium	Total	13.2	9.2	0.7	37.0
	Extract	0.266	0.206	0.013	0.698
Chromium	Total	6.0	8.0	1.0	28.0
	Extract	0.07	0.05	0.01	0.15
Copper	Total	269.0	511.0	11.0	2,140.0
	Extract	1.03	0.73	0.12	2.22
Iron	Total	46,870.0	41,410.0	15,400.0	148,000.0
	Extract	108.9	154.6	0.41	493.0
Lead	Total	12,270.0	10,920.0	291.0	34,600.0
	Extract	2.81	1.42	0.17	5.5
Manganese	Total	1,298.0	3,783.0	8.0	15,600.0
	Extract	5.28	6.22	0.12	16.8
Mercury	Total	0.78	0.72	0.07	2.8
	Extract	0.012	0.034	0.001	0.11
Nickel	Total	11.4	10.1	3.0	42.0
	Extract	0.09	0.06	0.01	0.21
Silver	Total	58.0	45.0	4.0	176.0
	Extract	0.03	0.03	0.01	0.11
Zinc	Total	743.0	721.0	78.0	2,800.0
	Extract	37.2	29.9	2.2	98.0

¹ Statistics on total metals based on analysis of 18 samples and reported in mg/kg; extract metals were measured in saturated paste extracts (reported in mg/L) and are based on 10 samples.

All metals except manganese are present in waste rock materials at levels much higher than found in U.S. soils (Brady, 1974). The average waste rock arsenic content (416 mg/kg) is an order of magnitude higher than the average range of arsenic commonly found in natural soils (0.1 to 40 mg/kg). The concentrations of lead in waste rock material (12,270 mg/kg) is two orders of magnitude higher than in natural soils (2 to 200 mg/kg). Concentrations of copper and zinc in waste rock material are more than twice as high as concentrations expected in natural soil (2 to 100 mg/kg for copper and 10 to 300 mg/kg for zinc).

Saturated paste extract metal concentrations are notably high for aluminum, arsenic, cadmium, iron, and zinc. Saturated paste metal concentrations were obtained by adding distilled water to a sample until saturation is reached. Samples are allowed to equilibrate for 24 hours and then extracted with a vacuum apparatus. This type of extract measures the soluble portion of elements in the sample. While this is a simple procedure and not directly comparable to total metal concentrations that might occur in a leachate from the material, it is an indicator of the elements that may become solubilized during a runoff event. Analysis of saturated paste extracts for metals is a good measure of the soluble portion of the total metal determination. Arsenic and cadmium are of particular concern because they are known carcinogens. Copper, zinc, and cadmium present problems to fisheries resources when concentrations of these metals exceed water quality criteria in surface water.

Saturated paste extract lead concentrations are also notable because of concerns about lead in the environment. The difference between the total extractable concentration of lead in the waste rock material and the soluble lead indicates that the solubility of lead is relatively low. The levels of total lead in waste rock confirmed field observations which noted ample quantities of lead present in ore minerals (primarily lead sulfate (galena)) in the waste rock dumps.

The heterogeneous nature of the waste rock material is indicated by the relatively high standard deviations measured in most of the elements analyzed (Table 5-4). As standard deviations approach or exceed the mean value, a large amount of intrasample and intersample variability is evident.

In addition to summary statistics presented in Table 5-4, statistics were computed for metal concentrations based on four depth categories. Samples were grouped into surface samples (0 to 1 inch), near-surface (approximately 12 to 36 inches), moderately deep (greater than 36 inches), and deep (greater than 10 feet). The two deep samples were collected during drilling of monitoring well HMW-5 at the top of the Block P Mine dump. Sample analysis were compared using a Students t statistic based on group means. Significance was based on a P value of 0.10.

Statistical differences were measured for some parameters when comparing paired values from the surface and near-surface groups. No differences were identifiable for any other parameters for any other group combination. Parameters which exhibited a statistical difference are presented in Table 5-5. Complete statistical calculations are presented in Appendix C-1.

Comparison of total metal concentrations showed that only lead has significantly different total concentrations between the two groups (Table 5-5). Lead concentrations in the surface interval (20,100 mg/kg) were significantly higher than in the near-surface interval (8,320 mg/kg). The reason for this relationship between the six surface and seven near-surface samples is unknown but the field sampling team did record the presence of considerable amounts of lead ore in most of the dumps sampled.

TABLE 5-5
SIGNIFICANT DIFFERENCES IN PHYSICOCHEMICAL PROPERTIES
BETWEEN SURFACE AND NEAR-SURFACE WASTE ROCK SAMPLES
GALENA CREEK PRELIMINARY ASSESSMENT

Parameter	Unit	Surface ¹	Near-Surface ²	P Value
EC	mmhos/cm	2.8	5.4	.07
Lead (total)	mg/kg	20,100	8,320	.05
Cadmium (extract)	mg/L	0.154	0.419	.07
Copper (extract)	mg/L	0.57	1.70	.02
Zinc (extract)	mg/L	20.0	55.4	0.09

1 Surface sample means based on 6 samples for EC and lead; 4 samples for cadmium, copper, and zinc.

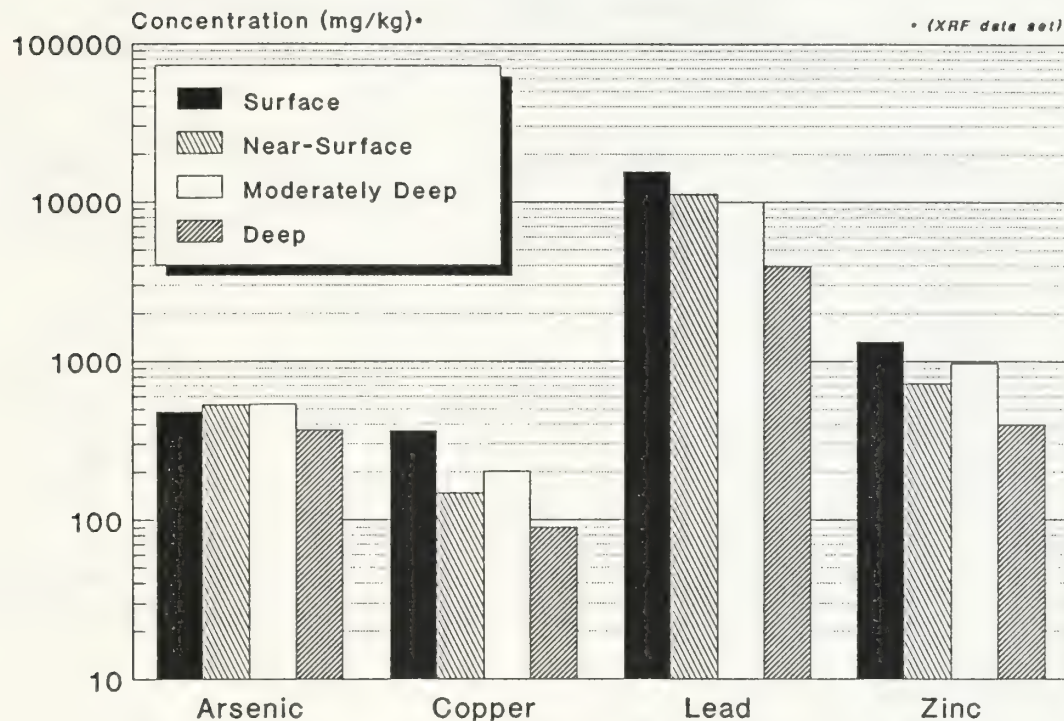
2 Near-surface sample means based on 7 samples for EC and lead; 4 samples for cadmium, copper and zinc.

Three extractable metal concentrations (cadmium, copper, and zinc) were higher in the near-surface samples than the surface interval (Table 5-5). Electrical conductivity volumes were lower ($P = 0.07$) in samples collected from the surface interval as compared to samples collected from the near-surface interval. The lower EC measured in the surface interval (2.8 mmhos/cm) is probably due to leaching of soluble constituents and is consistent with the differences measured in extractable metal concentrations.

Total metal concentrations measured with the XRF for samples not submitted to the laboratory were combined with total metal concentrations from the 18 laboratory samples to obtain an overall mean for all waste rock samples collected. Mean metal concentrations for arsenic, copper, iron, nickel, lead, and zinc in all waste rock samples collected are presented in Table 5-6. Total concentrations displayed in Table 5-6 closely compare to averages displayed in Table 5-4.

Metal concentrations from this data set were grouped both by depth and by mine dump location. Group means for total arsenic, copper, lead, and zinc from this XRF data set are displayed in Figure 5-2 for each of the depth intervals. Statistical analyses of group

Figure 5-2. Total Metal Concentrations by Depth Interval in Waste Rock Material



means showed that there were no significant differences between sampling depths. This finding does not confirm the decrease in lead concentration measured when comparing surface versus near-surface values determined by laboratory analysis (Table 5-5).

Comparison of dump location group means of metals concentrations are presented in Table 5-7. Significant differences ($P = 0.10$) were measured for copper, iron, nickel, lead, and zinc. Multiple comparisons were made using the Least Significant Difference (LSD) method. This method allowed only for approximations of differences in metals concentration between the mine dumps because the number of samples used to complete each calculation was variable.

TABLE 5-6
SUMMARY STATISTICS FOR METAL CONCENTRATIONS
IN WASTE ROCK MATERIAL
BY XRF AND LABORATORY ANALYSIS
GALENA CREEK PRELIMINARY ASSESSMENT

Element	Mean ¹ (mg/kg)	Standard Deviation	Minimum ² (mg/kg)	Maximum (mg/kg)
Arsenic	513	463	48	2,984
Copper	210	348	-20	2,140
Iron	38,090	29,290	10,120	148,000
Lead	11,800	10,860	291	52,000
Nickel	10	8	-5	42
Zinc	904	794	78	3,835

1 Summary statistics based on 42 samples.

2 Negative numbers indicate the predictive model could not estimate low concentrations.

TABLE 5-7
COMPARISON OF TOTAL METAL GROUP MEANS BASED ON
WASTE ROCK DUMP LOCATIONS
GALENA CREEK PRELIMINARY ASSESSMENT

Dump Name	N ¹	Concentration (mg/kg)					
		Arsenic	Copper	Iron	Lead	Nickel	Zinc
Block P	16	397	102	33,690	10,540 ⁺	8	665
Wright/Edwards	9	793	152	26,090	17,160	7	1,090
Liberty	5	597	170	29,020	16,430	5	747
Marcelline	4	567	163	31,020	14,920	9 ⁺	1,222
Danny T	2	446	320 ⁺	40,380	7,314 ⁺	19 [*]	2,522 [*]
Carter	6	321	614 [*]	79,330 [*]	2,652 [*]	19 [*]	640

1 N = number of samples.

* Asterisk indicates significant difference (P = 0.10) for marked samples.

+ Plus indicates group mean is not significantly different than mean marked with an asterisk.

Differences between group means were most apparent in samples collected from the Carter and Danny T dumps (Table 5-7). Material in the Carter dump has significantly higher concentrations of iron than any of the other dumps. The Carter dump also has higher concentrations of copper than all other dumps except for the Danny T. The Carter dump has lower concentrations of lead than the Marcelline, Liberty, and Wright and Edwards. Material in the Carter and Danny T dumps contains nickel concentrations that are higher than the Block P, Wright and Edwards, and Liberty dumps (Table 5-7).

Waste rock material in the Danny T dump contained significantly higher zinc concentrations (2,522 mg/kg) than any of the five other dumps. However, this concentration is based on only two samples collected from the Danny T and probability levels become less correct with fewer numbers of samples.

5.3.2 Mill Waste

A total of 18 mill tailings samples were collected from the upper and lower Block P mill tailings ponds (Figure 5-1). All 18 samples were analyzed for total metals with the XRF. Seven samples were submitted for laboratory analysis of total metal concentrations and five samples were submitted for saturated paste extract metal concentrations.

The upper and lower mill tailings ponds cover an area of approximately 15 acres. An additional area of approximately one acre below the tailings ponds is affected by tailings eroded out of the upper pond (Figure 5-1). The lower tailings pond is contained behind an earthen berm constructed along its western and southern perimeter. The earthen berm is approximately three feet high at the northwestern end of the pond and 10 to 12 feet high at the pond's southern end. The two tailings ponds are separated by a 15 to 20 foot high natural bedrock bench. This bench is primarily composed of the Cambrian Wolsey Shale Formation and the Tertiary Wolf Porphyry (Witkind, 1971). The bench extends northward from the mill tailings to Gold Run Creek.

Material in the upper tailings pond was apparently distributed from the mill site by wooden flumes, remnants of which are still present along the western perimeter of the upper pond

and interspersed through the middle third of the upper pond. The upper pond is dissected by an erosion channel which empties directly into the lower pond at a point approximately two-thirds of the way down the pond (Figure 5-1).

Hand augering in the lower pond revealed a zone of very fine grained pyrite crystals (Sample sites SS-108 and SS-109; Figure 5-1) at a depth of approximately 48 to 66 inches. A zone of medium grey, very plastic and sticky silt loam to clay loam material was encountered at a depth of approximately 66 to 78 inches in this hole. The lower tailings were saturated with water at a depth of approximately 84 inches at sample site SS-109 (Figure 5-1). The original surface upon which the tailings were deposited was encountered at depths of approximately 72 to 92 inches at the north end of the lower pond. Sample site 109, located at the southern end of the lower pond (Figure 5-1), was hand augered to a depth of 132 inches without reaching the original ground surface.

The upper tailings pond contained a zone of dark grey clay loam material near the base of the tailings pond. This material was also observed in the bottom of the erosion channel and was covered with spotty areas of blue and yellow efflorescence. This dark grey zone was saturated with water almost throughout the length of the erosion channel. The thickest tailings (18-25 feet) in the upper pond are located at the southern end of the pond.

The physical characteristics of mill tailing samples from both the upper and lower ponds are similar. They are composed of yellow, grey, grey-brown, and dark grey sandy loam to clay loam material. No coarse fragments were observed in any of the samples collected. Table 5-8 summarizes mean physical characteristics for mill tailings samples submitted to the laboratory. Mean saturated paste extract pH was highly acidic at 1.6 standard units. Laboratory pH was consistent for all seven samples, ranging from a minimum of 1.5 to a maximum of 1.8. Electrical conductivity measurements were extremely high (mean of 25.4 mmhos/cm). Such a value indicates a large proportion of soluble components in the material.

TABLE 5-8
MEAN MILL TAILINGS PHYSICAL CHARACTERISTICS
GALENA CREEK PRELIMINARY ASSESSMENT

Parameter	Unit	Mean ¹	Standard Deviation	Minimum	Maximum
pH	standard	1.6	0.1	1.5	1.8
EC	mmhos/cm	25.4	7.6	14.4	37.3
Saturation	%	34	19	21	75

¹ Summary statistics based on 7 samples.

Table 5-9 presents mean laboratory determined total metal and saturated paste extract metal concentrations for mill tailings samples. Concentrations of total metals, both total and water extractable, were substantially higher in the mill tailings than in waste rock material. The most notable of these concentrations are water extractable aluminum, arsenic, copper, iron, manganese, mercury, and zinc. Standard deviations around most of the means are relatively high and in some cases exceed the mean value (e.g. manganese). High standard deviations indicate the heterogeneous nature of the mill tailings material.

The relatively higher solubility of arsenic, copper, and zinc in mill tailing samples than in waste rock materials is of particular concern because of the potential impacts from a sediment release to surface water. If mill tailings material were carried into Galena Creek or the Dry Fork of Belt Creek during a runoff event, soluble metals input from this source may severely impact the aquatic ecosystem. Relatively high total lead concentrations (compared to the mean for U.S. soils) were measured in the tailings material (5,227 mg/kg). Extractable lead concentrations (3.3 mg/L) were similar to extractable lead concentrations in waste rock material (2.8 mg/L). While direct comparisons of extractable metal concentrations to total metal concentrations cannot be made, the relative proportion of extractable lead to total lead is very low when compared to the proportion of extractable zinc to total zinc or extractable aluminum to total aluminum. This relationship supports the premise that lead is relatively immobile in the environment and is not subject

TABLE 5-9
AVERAGE CONCENTRATIONS OF TOTAL AND EXTRACTABLE METALS
IN MILL TAILINGS
GALENA CREEK PRELIMINARY ASSESSMENT

Parameter	Type ¹	Mean	Standard Deviation	Minimum	Maximum
Aluminum	Total	3,504.0	2,254.0	1,260.0	6,470.0
	Extract	860.0	689.0	206.0	1,870.0
Arsenic	Total	1,015.0	615.0	500.0	2,140.0
	Extract	217.0	223.0	13.0	500.0
Cadmium	Total	24.5	20.0	9.7	68.0
	Extract	5.3	3.5	1.7	9.9
Chromium	Total	3.6	3.6	1.0	10.0
	Extract	1.8	1.8	0.1	4.1
Copper	Total	283.3	197.9	79.0	688.0
	Extract	133.3	133.5	17.9	305.0
Iron	Total	73,400.0	37,610.0	27,300.0	141,000.0
	Extract	24,270.0	19,180.0	4,940.0	48,200.0
Lead	Total	5,227.0	3,590.0	2,070.0	10,600.0
	Extract	3.3	2.5	0.5	8.0
Manganese	Total	735.0	1,273.0	6.0	3,290.0
	Extract	2,584.0	3,823.0	1.9	8,700.0
Mercury	Total	0.54	0.30	0.20	1.0
	Extract	0.21	0.51	0.001	1.25
Nickel	Total	19.3	9.2	12.0	38.0
	Extract	3.3	1.9	1.3	5.7
Silver	Total	78.0	36.0	19.0	113.0
	Extract	0.5	0.4	0.14	1.25
Zinc	Total	674.0	300.0	76.0	950.0
	Extract	457.0	428.0	102.0	1,050.0

¹ Statistics on total metals based on analysis of 7 samples and reported in mg/kg; extract metals were measured in saturated paste extracts (reported in mg/L) and are based on 6 samples.

to a high degree of leaching. This relationship is also consistent with results of waste rock sample analysis (Section 5.3.1).

A comparison of summary statistics for mill tailings materials based on vertical intervals was also made. Three depth intervals were analyzed: the surface to one inch depth interval; a moderately deep interval (generally between 1 inch and 66 inches); and a deep interval (below 66 inches). Analysis of physical properties and total metal concentrations was completed during this evaluation using a student t statistic ($P = 0.2$) for differences between groups.

Only one significant difference was identifiable in the data set between the surface and moderately deep interval. No other statistical differences were apparent between any other group combination. The only significant difference measured was a higher EC in surface samples (33.6 mmhos/cm) than samples from the moderately deep interval (21.15 mmhos/cm). This difference may be due to wicking of metalliferous salts to the surface, although the difference was not confirmed by higher total metal concentrations in surface samples. Depth comparisons could not be computed on saturated paste extract metals due to an insufficient sample size.

In addition to laboratory analysis, total metal concentrations were analyzed with the XRF in mill tailings samples not submitted to the laboratory. This data set combines the seven laboratory analyzed samples with 11 additional mill tailings samples analyzed by XRF. The six metals included in the data set are arsenic, copper, iron, nickel, lead, and zinc. Summary statistics for two sample groupings are presented in Table 5-10.

Total metal concentrations shown in Table 5-10 compare reasonably well with total concentrations reported in Table 5-9. The larger size of this data set allows a better statistical analysis of depth related differences. Group means for total arsenic, copper, nickel, lead, and zinc from this XRF data set are displayed in Figure 5-3 for each of the depth intervals. Comparison of total metals concentrations in the various intervals showed a significantly higher concentration ($P = 0.2$) of nickel in the moderately deep interval (17 mg/kg) as compared to surface samples (13 mg/kg). Four metals had

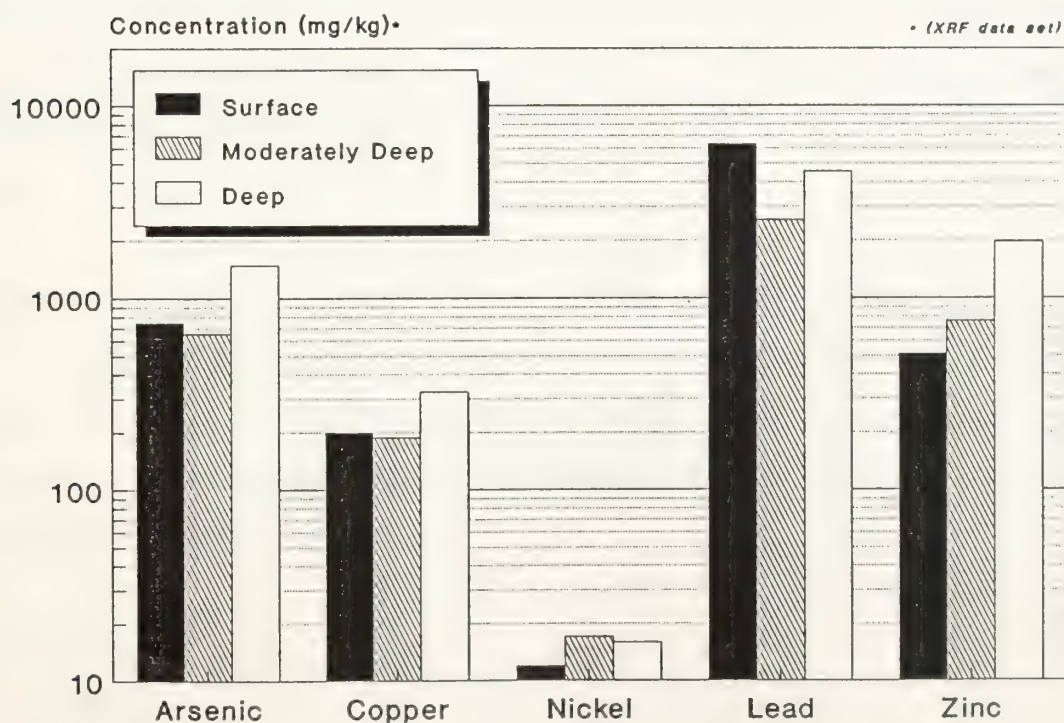
TABLE 5-10
SUMMARY STATISTICS FOR TOTAL METALS CONCENTRATIONS IN MILL TAILINGS
BY XRF AND LABORATORY ANALYSIS
GALENA CREEK PRELIMINARY ASSESSMENT

Element	Mean ¹ (mg/kg)	Standard Deviation	Minimum ² (mg/kg)	Maximum (mg/kg)
Arsenic	1,045	697	297	2,648
Copper	266	180	19	688
Iron	62,100	30,180	22,410	141,000
Lead	4,575	3,459	-1,086	10,600
Nickel	16	7	8	38
Zinc	1,039	1,100	76	4,110

1 Summary statistics based on 42 samples.

2 Negative numbers indicate the predictive model could not estimate low concentrations.

**Figure 5-3. Total Metal Concentrations
by Depth Interval in Mill Tailings**



significantly different concentrations when surface samples were compared with the deeper interval. Surface samples had lower concentrations of arsenic (746 mg/kg), copper (199 mg/kg), iron (46,840 mg/kg) and nickel (12 mg/kg) than the deep interval (1,486, 326, 69,220, and 16 mg/kg, respectively).

5.3.3 Streamside Tailings

A total of 18 streamside tailings samples were collected from three different streamside tailings deposits in the Galena Creek and Dry Fork of Belt Creek drainages. The largest of these deposits is located at the confluence of the Dry Fork with Bender Creek (Figure 5-1). These streamside tailings represent material that was probably washed down from the Block P Mill tailings ponds during one or more flood events that have occurred several times since the mill tailings were deposited. Samples collected from site SS-102 (Figure 5-1) showed evidence of several flooding events. This evidence included the presence of several organic layers developed between layers of tailings material.

Streamside tailings were predominantly composed of yellow, red-brown, brown, and grey sand to loamy sand textured material. At almost all sites sampled, streamside tailings overlaid angular gravel deposits which exhibited heavy coatings of red-brown iron oxides. Streamside tailings thicknesses were greatest at the Bender Creek location, ranging from a minimum of 18 inches to a maximum of 60 inches. Streamside tailings elsewhere along Galena Creek were predominantly deposited as a thin veneer ranging from six to 24 inches thick.

Mean values of pH, Ec, and saturation percent for streamside tailings are presented in Table 5-11. Average saturated paste extract pH is acidic at 2.9 standard units. Electrical conductivity averages 1.6 mmhos/cm, a value indicative of low to moderate concentrations of soluble constituents. Saturation averaged 28% indicating a moderate amount of water holding capacity.

TABLE 5-11
AVERAGE STREAMSIDE TAILINGS PHYSICAL CHARACTERISTICS
GALENA CREEK PRELIMINARY ASSESSMENT

Parameter	Unit	Mean ¹	Standard Deviation	Minimum	Maximum
pH	standard	2.9	0.7	2.0	4.1
EC	mmhos/cm	1.6	1.3	0.4	4.1
Saturation	%	28	6	21	37

¹ Summary statistics based on 9 samples.

Table 5-12 presents statistical summaries of laboratory determined total metal and saturated paste extract metal concentrations in streamside tailings material. Total metal concentrations in streamside tailings compare very well with total metal concentrations measured in mill tailings materials. The streamside tailings have substantially less extractable metal concentrations than mill tailings, however, by a factor of two orders of magnitude for most of the elements analyzed. The only exception to this relationship is the concentration of extractable zinc (142 mg/L in streamside tailings versus 457 mg/L in mill tailings). The substantial difference in concentration of soluble metals in streamside tailings versus mill tailings is probably a function of the high degree of leaching which occurs in a streamside environment.

Statistical analyses of group means based on depth intervals were used to determine differences in metal concentrations with depth. Samples were separated into three intervals including a surface interval (0 to 1 inch), a near-surface interval (1 to approximately 15 inches), and moderately deep interval (greater than approximately 15 inches). This particular comparison could not be applied to saturated paste extract metal concentrations due to the small number of samples within this sample group analyzed for extractable metals. No statistical differences were detected between group means for any selected interval for any of the total metals analyzed.

TABLE 5-12
AVERAGE CONCENTRATIONS OF TOTAL AND EXTRACTABLE METALS
IN STREAMSIDE TAILINGS
GALENA CREEK PRELIMINARY ASSESSMENT

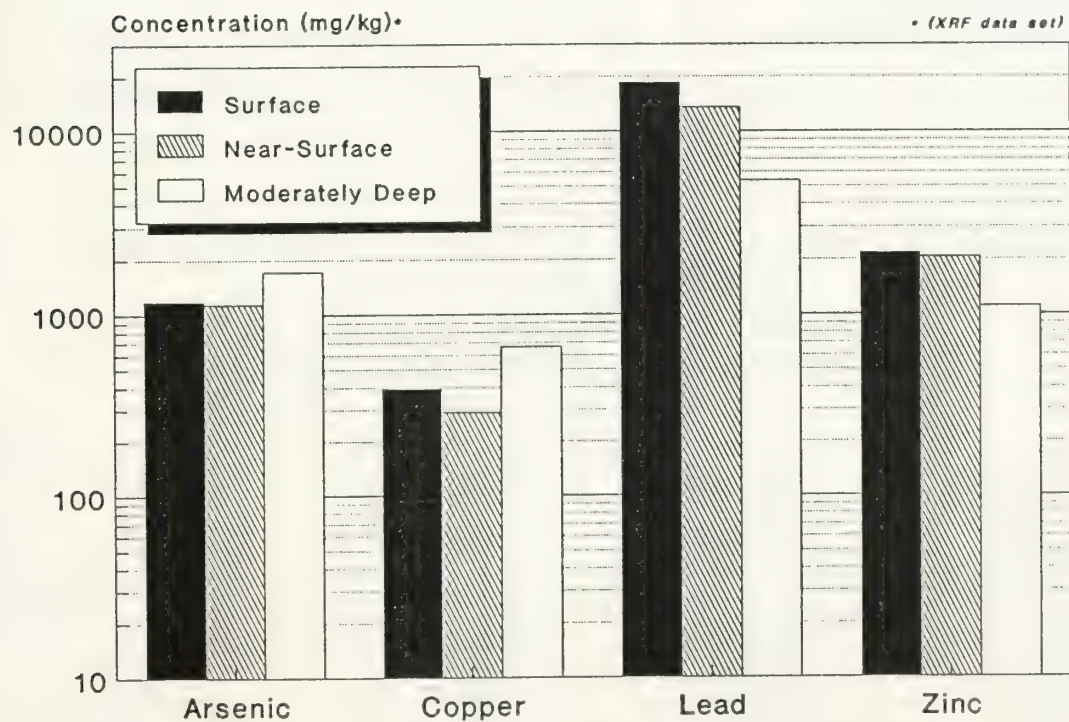
Parameter	Type ¹	Mean	Standard Deviation	Minimum	Maximum
Aluminum	Total	3,964.0	2,678.0	1,610.0	9,110.0
	Extract	4.0	5.5	0.5	15.0
Arsenic	Total	1,011.0	750.0	16.0	2,040.0
	Extract	0.05	0.03	0.002	0.09
Cadmium	Total	18.0	10.7	9.0	44.0
	Extract	0.70	0.56	0.06	1.5
Chromium	Total	9.2	11.1	1.0	34.0
	Extract	0.04	0.04	0.01	0.12
Copper	Total	295.0	142.0	130.0	568.0
	Extract	1.2	1.3	0.3	3.6
Iron	Total	36,310.0	19,390.0	12,300.0	65,400.0
	Extract	22.5	46.0	0.2	116.0
Lead	Total	10,460.0	7,391.0	408.0	18,600.0
	Extract	1.7	2.2	0.1	5.7
Manganese	Total	209.0	427.0	26.0	1,340.0
	Extract	11.2	22.9	0.3	57.8
Mercury	Total	0.71	0.66	0.05	2.1
	Extract	0.01	0.02	0.001	0.045
Nickel	Total	16.3	6.8	10.0	28.0
	Extract	0.06	0.08	0.01	0.19
Silver	Total	142.0	137.0	2.0	440.0
	Extract	0.01	0.08	0.01	0.03
Zinc	Total	1,578.0	1,437.0	553.0	4,830.0
	Extract	142.0	151.0	8.7	401.0

¹ Statistics on total metals based on analysis of 9 samples and reported in mg/kg; extract metals were measured in saturated paste extracts (reported in mg/L) and are based on 6 samples.

In addition to laboratory analysis, total metal concentrations were analyzed with the XRF for streamside tailings samples not analyzed at the laboratory. This data set combines the nine laboratory analyzed samples with the remaining nine streamside tailings samples analyzed by XRF. Summary statistics for this data group are presented in Table 5-13.

Total metal concentrations shown in Table 5-13 compare reasonably well with total concentrations reported in Table 5-12. The larger size of this data set allows a better statistical analysis of depth related differences. Group means for total arsenic, copper, lead, and zinc from this XRF data set are displayed in Figure 5-4 for each of the depth intervals. Group means were significantly different ($P = 0.2$) for lead. Total lead concentrations in the lowest depth interval (greater than approximately 15 inches) was significantly lower than either the surface or near-surface depth interval.

Figure 5-4. Total Metal Concentrations by Depth Interval in Streamside Tailings



5.3.4 Native Soil

Four native soil samples were collected from below mine and mill waste deposits. Sample sites include SS-100, SS-105, SS-112 and SS-134 (Figure 5-1). Two of these samples were collected below the Bender Creek streamside tailings, one below the Block P Mill tailings, and one below the Marcelline waste rock dump. Review of laboratory analyses (Appendix C-2) indicates that leaching of metals from overlying deposits into the underlying native soils at these sites may be occurring but this conclusion is not quantifiable with the few samples collected during the PA.

Of the four native soil samples collected, soil at sample site SS-112 (located on the upper mill tailings pond) exhibited a very similar chemistry to the overlying mill tailings. Electrical conductivity and pH for the native soil sample (20.1 mmhos/cm and 1.8 su) respectively, were similar to EC and pH for the average mill tailings value (27.2 mmhos/cm and 1.6 su Table 5-11). Concentrations of saturated paste extract metals also compares well for both sample types (see Appendix C-2). However, due to the limited amount of data, direct comparison of physicochemical data cannot be supported with confidence due to a lack of background data on native uncontaminated material.

TABLE 5-13
SUMMARY STATISTICS FOR TOTAL METAL CONCENTRATIONS
IN STREAMSIDE TAILINGS
BY XRF AND LABORATORY ANALYSIS
GALENA CREEK PRELIMINARY ASSESSMENT

Element	Mean ¹ (mg/kg)	Standard Deviation	Minimum ² (mg/kg)	Maximum (mg/kg)
Arsenic	1,222	904	16	3,744
Copper	397	361	105	1,464
Iron	39,430	18,800	12,300	77,060
Lead	14,300	11,110	408	43,970
Nickel	20	16	3	75
Zinc	1,944	1,624	408	6,037

¹ Summary statistics based on 42 samples.

² Negative numbers indicate the predictive model could not estimate low concentrations.

6.0 DATA VALIDATION

6.1 ACCURACY

Accuracy is a measure of the ability of an analytical procedure to determine the actual quantity of a particular analyte in a sample. In these studies, laboratory accuracy was evaluated using blind field standards (BFS) and laboratory matrix spikes as quality control samples. Blind field standards used in this investigation were certified standards prepared by Environmental Resource Associates (ERA).

The BFS samples were submitted for analysis along with natural samples. Although the laboratory can often recognize the BFS sample, the specific contents and parameter concentrations are unknown to laboratory personnel. Blind field standards submitted to the laboratory during the Galena Creek Preliminary Assessment contained chemical parameters at concentrations similar to those expected in natural samples.

Two blind field standard sets were submitted for analysis with natural surface, groundwater, and soil samples. The natural samples, from each medium, were divided into two groups. One BFS sample was analyzed with each group. A minimum of two samples were required to provide adequate data to perform accuracy calculations.

Accuracy statements were generated by comparing laboratory results to the certified expected result provided by the manufacturer. A statistical analysis is applied to the following expression.

"The accuracy of a parameter is (mean)% \pm (1.96 x SD)%"

where:

parameter = a particular analyte in the blind field standard and natural sample

mean = average of reported analytical values

SD = standard deviation, defined as

$$SD = \Sigma \left[\frac{(Recovery_i - Recovery_{avg})^2}{n-1} \right]^{\frac{1}{2}}$$

n = number of BFS samples.

The accuracy statements for this project are presented in Tables 6-1 through 6-3. Information contained on these tables includes the total number of blind field standards submitted for analysis, average percent recovery, maximum uncertainty, and completeness for each parameter. Target accuracy levels for similar projects are usually set to achieve an 80% confidence level with a \pm 20% deviation.

6.1.1 Surface Water Accuracy

Accuracy was calculated for all major analytes in surface water samples (Table 6-1). Analytes falling outside the manufacturers' established ranges included total and dissolved

TABLE 6-1
SURFACE WATER ACCURACY STATEMENT

Parameter	# Samples	Accuracy (avg. % recovered)	Maximum Uncertainty	Standard Deviation
Aluminum	2	120.97	167.7	120.97
Arsenic	2	111.65	154.9	111.76
Barium	2	68.49	94.9	68.49
Cadmium	2	109.78	152.2	109.83
Calcium	2	116.95	1.2	0.85
Chloride	2	96.50	1.2	0.88
Chromium	2	144.44	200.2	144.44
Copper	2	99.24	137.5	99.24
Iron	2	101.45	140.6	101.45
Lead	2	170.45	236.2	170.46
Magnesium	2	106.00	0.0	0.00
Manganese	2	100.61	139.5	100.66
Mercury	2	110.71	153.5	110.72
Nickel	2	94.32	130.8	94.40
Nitrate	2	98.37	136.3	98.37
Potassium	2	87.87	0.0	0.0
Selenium	2	109.76	152.2	109.82
Silver	2	31.54	43.8	31.58
Zinc	2	103.17	143.0	103.21
Disaluminum	2	120.97	167.7	120.97
Disarsenic	2	101.94	141.4	102.06
Disbarium	2	102.74	150.1	108.30
Discadmium	2	106.52	147.6	106.52
Dischromium	2	122.22	169.4	122.22
Discopper	2	99.24	137.5	99.24
Disiron	2	101.45	140.6	101.45
Dislead	2	170.45	236.2	170.46
Dismanganese	2	100.61	139.5	100.66
Dismercury	2	110.71	153.5	110.72
Disnickel	2	94.32	130.8	94.40
Disselenium	2	107.93	149.6	107.94
Dissilver	2	28.46	39.5	28.50
Diszinc	2	103.17	143.0	103.21
Fluoride	2	91.16	7.2	5.18
Hardness	2	112.50	0.7	0.50
Sodium	2	106.55	0.2	0.16
Sulfate	2	105.78	0.6	0.47
TDS	2	94.97	0.4	0.30
Total Alkalinity	2	105.08	2.8	2.03

TABLE 6-2
GROUNDWATER ACCURACY STATEMENT

Parameter Dissolved Metals	# Samples	Accuracy (avg. % recovered)	Maximum Uncertainty	Standard Deviation
Aluminum	2	80.65	111.8	80.65
Arsenic	2	85.44	118.4	85.44
Barium	2	136.99	189.9	136.99
Cadmium	2	109.78	152.2	109.79
Calcium	0	(1)	(1)	0
Chloride	0	(1)	(1)	0
Chromium	2	100.00	138.7	100.07
Copper	2	103.05	142.9	103.12
Fluoride	0	(1)	(1)	0
Hardness	0	(1)	(1)	0
Iron	2	126.81	175.8	126.86
Lead	2	96.59	134.0	96.65
Magnesium	0	(1)	(1)	0
Manganese	2	77.74	113.6	81.95
Mercury	2	141.67	199.4	143.86
Nickel	2	89.15	124.6	89.90
Nitrate	2	100.66	139.5	100.66
Potassium	0	(1)	(1)	0
Selenium	2	102.44	142.1	102.56
Silver	2	30.77	42.6	30.77
Sodium	0	(1)	(1)	0
Sulfate	0	(1)	(1)	0
TDS	0	(1)	(1)	0
Total Alkalinity	0	(1)	(1)	0
Zinc	2	105.82	146.7	105.82

(1) No sample data available

Table 6-3

silver and potassium. Silver appears to be an unstable analyte in the ERA standard. Chen-Northern's laboratory historically has had difficulty analyzing silver to achieve concentrations within the range set by the manufacturer. Because the other analytes are acceptable, the ERA standard continues to be used. Analyses of potassium in the BFSs were outside the set range of 274 to 336 mg/l at 268 mg/l. In general, the accuracy achieved by Chen-Northern's laboratory for surface water samples was acceptable.

6.1.2 Groundwater Accuracy

Accuracy was calculated for all major analytes in groundwater samples (Table 6-2). Analytes falling outside the manufacturers' established ranges for BFS's included manganese, mercury and silver. In our judgement, silver is out of range for the same reasons explained in Section 6.1.1.

The recovery of manganese in two BFS samples differed considerably. One sample fell inside the manufacturers range, the other was substantially lower than the acceptable range. The two mercury analyses recovered in the BFS samples were also dissimilar. One analysis was within the range, the other was significantly higher than the stated range of acceptable values. Because of this, manganese and mercury data were flagged in the groundwater data base (Appendix B-2).

6.1.3 Soil Accuracy

Evaluations of accuracy in soil sample analyses has yet to be completed. Accuracy statements for soils data will be included in the final PA report.

6.2 PRECISION

Precision is a measure of the mutual analytical agreement of individual measurements of duplicate samples. In these studies, field and laboratory duplicate samples were used to evaluate precision. Tables 6-4 through 6-6 are precision statements for surface water, groundwater, and soil data sets, respectively.

**TABLE 6-4
SURFACE WATER PRECISION STATEMENT**

Parameter	# Samples	Precision	Maximum Uncertainty
Aluminum	2	-6.14	28.25
Arsenic	2	4.43	18.04
Barium	2	0.00	0.00
Cadmium	2	7.39	14.81
Calcium	2	-2.17	8.43
Chloride	2	0.00	0.00
Chromium	2	-14.29	39.60
Copper	2	-2.44	6.76
Iron	2	2.05	4.03
Lead	2	-1.11	7.71
Magnesium	2	0.00	0.00
Manganese	2	-4.04	14.98
Mercury	2	0.00	0.00
Nickel	2	-30.58	60.41
Nitrate	2	0.00	0.00
Potassium	2	0.00	0.00
Selenium	2	0.00	0.00
Silver	2	86.67	240.28
Zinc	2	2.05	7.32
Disaluminum	2	33.33	92.40
Disarsenic	2	0.00	0.00
Disbarium	2	0.00	0.00
Discadmium	2	8.47	23.49
Dischromium	2	0.00	0.00
Discopper	2	27.69	59.40
Disiron	2	3.80	8.67
Dislead	2	81.82	226.79
Dismanganese	2	-4.04	14.98
Dismercury	2	0.00	0.00
Disnickel	2	19.05	41.74
Disselenium	2	0.00	0.00
Dissilver	2	0.00	0.00
Diszinc	2	1.29	6.47
Fluoride	2	3.51	9.73
Hardness	2	-1.60	5.71
Sodium	2	-4.35	12.05
Sulfate	2	-0.68	2.49
TDS	2	-8.09	18.38
Total Alkalinity	2	17.78	35.92

TABLE 6-5
GROUNDWATER PRECISION STATEMENT

Parameter Dissolved Metals	# Samples	Precision	Maximum Uncertainty
Aluminum	2	3.70	10.27
Arsenic	2	-2.86	7.92
Barium	2	0.00	0.00
Cadmium	2	0.52	1.45
Calcium	2	1.82	5.04
Chloride	2	0.00	0.00
Chromium	2	0.00	0.00
Copper	2	0.00	0.00
Fluoride	2	-2.44	6.76
Hardness	2	0.65	3.98
Iron	2	6.85	37.13
Lead	2	3.61	10.02
Magnesium	2	-2.04	5.66
Manganese	2	0.00	20.63
Mercury	2	0.00	0.00
Nickel	2	28.57	56.00
Nitrate	2	-112.22	228.84
Potassium	2	0.00	0.00
Selenium	2	0.00	0.00
Silver	2	-3.24	97.02
Sodium	2	6.67	18.48
Sulfate	2	-14.02	27.97
TDS	2	-4.88	13.52
Total Alkalinity	2	2.21	6.12
Zinc	2	-2.13	5.90

(1) No sample data available

Table 6-6

6.2.1 Field Precision

Parameter-specific field precision statements were developed by assessing the results from natural samples and field duplicates collected during the Galena Creek Preliminary Assessment sampling. Two field duplicate samples were collected during the surface water, groundwater and soil sampling episodes. Results from a minimum of two duplicate samples are needed to perform precision calculations.

The procedure for obtaining duplicates included collecting a separate sample of the same medium using identical sampling techniques as those used to collect the natural samples. The duplicate samples, therefore, are more a measure of the natural variation of an environmental system and consistency in sampling techniques. This method cannot ensure the duplicate represents the same surface water, groundwater, or soil "population." Since the duplicate is not a "split", a certain amount of variation between duplicate and natural sample results will occur.

Duplicate and natural sample results were used to calculate a Relative Percent Difference (RPD) for each chemical parameter using the following formula.

$$RPD = \frac{(X_1 - X_2)}{\left(\frac{(X_1 + X_2)}{2} \right)} \times 100$$

where:

x_1 - concentration of the natural parameter

x_2 - concentration of the duplicate parameter

The standard deviation (SD) can be used to indicate the range of the RPD's by the following expression.

"The precision of parameter is $\pm (1.96 \times \text{S.D.})\%$ "

$$SD = \Sigma \left[\frac{(\text{Recovery}_i - \text{Recovery}_{avg})^2}{n-1} \right]^{\frac{1}{2}}$$

n = number of samples.

6.2.2 Laboratory Precision

The precision of laboratory techniques was assessed by analyzing two aliquots of a single sample and comparing analytical consistency by calculating the Relative Percent Difference (RPD) of those results. Laboratory duplicates were produced and analyzed in the lab concurrently with natural samples at the frequency described in the Field Sampling Plan (Chen-Northern, 1990b). Analytical results from laboratory duplicates were reported with natural sample data and are included in the project databases (Appendices A, B-2, and C-2).

From Tables 6-4 through 6-6, maximum uncertainty represents the value for $(1.96 \times \text{S.D.})\%$ for each parameter. No RPD's were calculated for parameters below detection limit. For parameters near the detection limit, the precision statements may give large ranges of relative precision. For a normal distribution, 95% of all data will fall inside the precision range.

6.3 REPRESENTATIVENESS

Representativeness is a measure of how closely the samples collected represent the

population from which they were obtained. Representativeness is obtained by:

- ♦ Choosing the number of samples, sampling locations, and sampling procedures that depict, as accurately and precisely as possible, the matrix and conditions being measured,
- ♦ Following protocols for storage, preservation, and transportation that preserve the true condition of the collected sample,
- ♦ Analyzing samples within the prescribed holding times, and,
- ♦ Using appropriate and approved analytical methods.

Representativeness was addressed during the planning stages of this Preliminary Assessment, and is presented in detail in the project sampling and analysis plan (Chen-Northern, 1990b). In addition, representativeness in water samples is assessed by the detection of bias due to contamination in cross-contamination blanks. To detect contamination and identify the source, analytical results from field blanks were compared with instrument detection limits. Any detectable concentration in a particular parameter is considered contaminated.

Environmental water sampling conducted during the Galena Creek Preliminary Assessment incorporated cross-contamination blanks into the natural sample group as quality control samples. QC samples included in surface water and groundwater sampling episodes were prepared by collecting a sample of deionized water which had been run through decontaminated sampling equipment. The rinse water was bottled and labeled with a station identifier to conceal the true nature of the QC sample. This way, the cross-contamination samples were processed along with natural samples and lab personnel were unaware of the identity of the QC samples.

6.3.1 Surface Water Representativeness

Detectable concentrations of chromium, manganese, sulfate and sodium were present in cross contamination blank samples associated with the surface water data set. We determined that measured exceedances were not significant but appropriate flags are included in the surface water data base (Appendix A).

6.3.2 Groundwater Representativeness

The groundwater cross contamination blank samples exceeded detection limits for the following parameters: nitrate + nitrite as N, sulfate, cadmium, chromium, iron, manganese, and silver. The level of contamination was consistent in both nitrogen samples at 0.15 mg/l. Of the two cross-contamination samples collected for each parameter, only one of the sulfate, cadmium, chromium, iron, and manganese samples were contaminated. Appropriate flags were assigned to the groundwater data base (Appendix B-2) to reflect these exceedances.

6.4 COMPLETENESS

Completeness for environmental sampling was assessed by comparing the number of valid natural samples to the number of samples collected and to the number of samples planned. Valid samples are those which have not exceeded holding times and were collected by approved methods.

Tables 6-7 through 6-9 present completeness results for the surface water, groundwater, and soil sampling episodes. For this study a completeness of 90% was projected in the project sampling and analysis plan (Chen-Northern, 1990b). This value was attained for all matrices sampled except groundwater.

TABLE 6-7
SURFACE WATER COMPLETENESS SUMMARY, GALENA CREEK PRELIMINARY
ASSESSMENT; OCTOBER, 1990

	Samples Proposed	Samples Collected	Percent Valid	Percent Completeness
Natural Samples	17	15	100	88
Field Duplicates	2	2	100	100
Cross- Contam. Blanks	2	2	100	100
Blind Field Standards	2	2	100	100
Laboratory Duplicates	2	2	100	100
Laboratory Spikes	2	2	100	100
TOTAL	27	25	100	93

TABLE 6-8
GROUNDWATER COMPLETENESS SUMMARY, GALENA CREEK
PRELIMINARY ASSESSMENT; OCTOBER, 1990

	Samples Proposed	Samples Collected	Percent Valid	Percent Completeness
Natural Samples	12	9	100	75
Field Duplicates	2	2	100	100
Cross- Contam. Blanks	2	2	100	100
Blind Field Standards	2	2	100	100
Laboratory Duplicates	2	2	100	100
Laboratory Spikes	2	2	100	100
TOTAL	22	19	100	86

TABLE 6-9
SOIL COMPLETENESS SUMMARY, GALENA CREEK PRELIMINARY ASSESSMENT;
OCTOBER, 1990

	Samples Proposed	Samples Collected	Percent Valid	Percent Completeness
Natural Samples	49	43	100	87
Field Duplicates	2	2	100	100
Cross- Contam. Blanks	2	2	100	100
Blind Field Standards	2	2	100	100
Laboratory Duplicates	2	4	100	200
Laboratory Spikes	2	2	100	100
TOTAL	59	53	100	90

6.5 COMPARABILITY

The objective of a comparability assessment is to insure that data developed during the investigation are directly comparable (or within defined limitations) to existing data. We assessed comparability for the surface water data collected during the Galena Creek Preliminary Assessment by comparing it to historical data collected by the Montana Department of Natural Resources and Conservation (DNRC).

Comparability of environmental data is achieved by adopting standard sampling and analytical procedures and by reviewing data from other sources. The methods used for the Galena Creek Preliminary Assessment were consistent with the current standards of practice.

Environmental samples collected by the DNRC were analyzed by the State Department of Health and Environmental Sciences Chemistry Laboratory, Helena, Montana. The State lab holds EPA certification and follows industry accepted methods and procedures, including those of the U.S. Geological Survey and the EPA.

6.5.1 Surface Water Comparability

Parameters analyzed during sampling programs completed by the State of Montana and Chen-Northern varied in type and analytical detection limits. Table 6-10 summarizes parameters and detection limit goals used by each lab in the analysis of surface water samples. It is noteworthy that not all samples collected by DNRC were analyzed for the entire parameter list in Table 6-10. In fact, most samples were only analyzed for a small number of parameters included in Table 6-10.

TABLE 6-10
COMPARISON OF SURFACE WATER PARAMETER LISTS AND DETECTION LIMITS
FOR GALENA CREEK PRELIMINARY ASSESSMENT
AND MDNRC SURFACE WATER DATA

PARAMETER	CHEN-NORTHERN	DHES/DNRC
Total Hardness	1	1
Calcium	1	1.0
Magnesium	1	1.0
Sodium	1	1.0
Potassium	1	.50
Total Alkalinity	1	1
Carbonate as CaCO ₃	1	1.0
Bicarbonate as HCO ₃	1	1.0
Chloride	1	0.1 ^(b)
Fluoride	0.05	(c)
Sulfate	1	1.0
TSS	1	(c)
TDS	1	(c)
Turbidity	1.0 NTU	1.0 JTU
Nitrate + Nitrites as N	0.01	(c)
Aluminum	0.1	.01
Arsenic	0.002	0.001 - 0.01
Barium	0.1	(c)
Cadmium	0.0001	0.01-0.001
Chromium	0.001	(c)
Copper	0.02	0.01
Iron	0.05	.01
Lead	0.001	.01
Lithium	N/S	0.01
Manganese	0.015	0.02 ^(b)
Mercury	0.0002	0.0002
Nickel	0.002	(c)
Selenium	0.005	0.001
Silver	0.0001	0.05
Zinc	0.02	0.04 ^(b)
pH (s.u.)	0.1 s.u.	0.01 s.u.
Conductivity (μ mhos/cm@ 25C)	1	0.1
Sodium Adsorption Ratio	0.01	0.1

(a) Detection limits ascertained from DNRC data, 1973-1977

(b) Lowest available reported value from which detection limit was determined

(c) Not analyzed

7.0 CONCLUSIONS

This section presents conclusions reached through review of existing data and information gathered as a result of completion of this PA. In addition, we have preliminarily identified operable units in the Galena Creek drainage and we have prioritized these operable units with respect to environmental impacts.

7.1 CONCEPTUAL MODEL OF SITE PROCESSES

Figure 7-1 is a conceptual model which illustrates the various types of contaminant source areas in the study area. In addition, the figure shows the primary means by which contaminants are transported in the PA study area and locations where natural abatement of these contaminants occur. The following subsections describe contaminants of concern in the area, sources of these contaminants, pathways by which contaminants move in the environment, and receptors of site contaminants. Finally, problems within the study area are described.

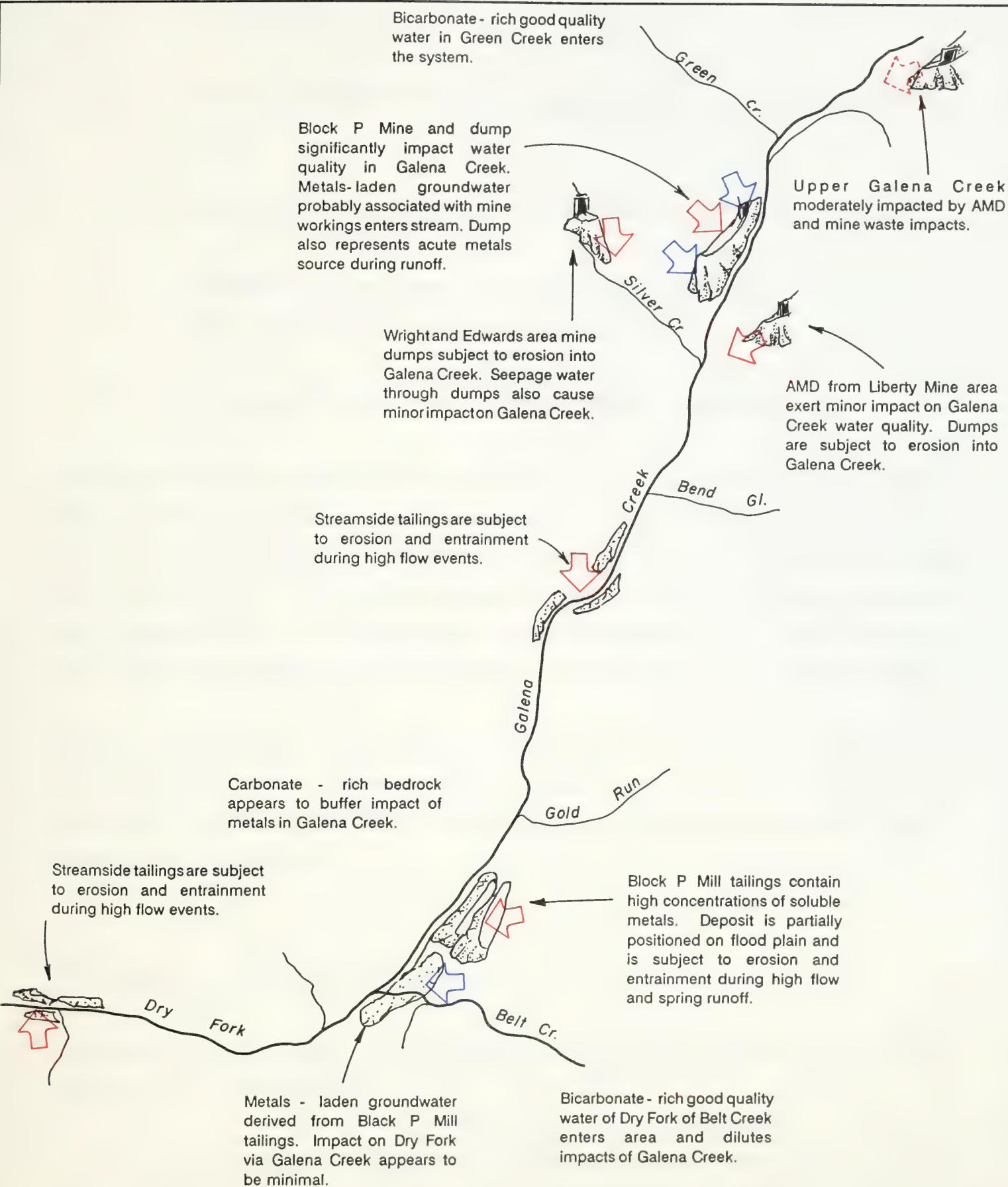
7.1.1 Contaminants of Concern

The primary contaminants of concern in the Galena Creek drainage are metals. Specific metals which impact the environment to some degree include arsenic, lead, cadmium, zinc, copper, iron, and manganese. Concentrations of copper, cadmium, and zinc in the lower three-fourths of Galena Creek exceed both acute and chronic ambient water quality criteria. As a result, the fisheries and aquatic environment in the stream is impacted.

7.1.2 Contaminant Sources

Project scientists identified several source areas for the metals of concern in the study area. These include:

- ◆ Abandoned underground mine workings associated with the Block P Mine and possibly the Wright-Edwards Mine.



Primary areas of contaminant input via groundwater.

Primary areas of contaminant input via mine waste erosion and entrainment.

Conceptual Model of
Processes and Environmental Problems
Hughesville/Barker Mining District
FIGURE 7-1

- ◆ The historic Block P Mill tailings impoundments near the mouth of Galena Creek.
- ◆ Mine waste dumps associated with several historical mines in the area.
- ◆ Streamside tailings located along both Galena Creek and the Dry Fork of Belt Creek below its confluence with Galena Creek.
- ◆ Underground workings associated with other mines in the area.

The source of metals in the underground workings associated with the historic Block P Mine and other area mines is probably associated with the sulfide-rich ore deposits on the surface of the underground tunnels and shafts. The mechanism for producing acid mine drainage in the underground involves interaction of sulfide minerals, oxygen and water. The acidic water condition produced from the reaction causes metals to become soluble and mobilize into adjacent groundwater, surface water, and soil environments.

Certain metals in the mine waste dumps and tailings ponds in the study area are easily solubilized by water. Because of this, any water which contacts these materials through inundation, infiltration, or submersion solubilizes certain metals which are then subject to transport in the environment.

7.1.3 Pathways of Contaminant Movement

Contaminants in the Galena Creek drainage move in the environment via several mechanisms. These include:

- ◆ Groundwater -- Metals enter groundwater systems in the study area when groundwater levels rise and contact the source areas and when precipitation infiltrates through source areas and into the groundwater. The former mechanism of contaminant contact with groundwater is most

prominent in the underground mine workings in the area. Precipitation infiltration occurs to some degree wherever contaminant source areas are present at or near the ground surface.

- ◆ Erosion and Entrainment -- Surficial contaminant source areas are subject to erosion through several processes. These include detachment by rainfall, overland flow, concentrated surface flow in rills and gullies, or inundation through changes in stream stage. Once metal contaminants are eroded, they are subject to entrainment in the water and subsequent transport. Depending upon the magnitude of the runoff event, the metals entrained in runoff may be carried to a receiving stream, such as Galena Creek. Metals in runoff water are transported either in dissolved state or in suspension, depending upon the quantity of flow and the pH and Eh of the runoff water.
- ◆ Wind Erosion and Entrainment -- Wind-borne erosion and transport of surficial source areas is also possible. The significance of this method of transport is primarily dependent on the antecedent moisture conditions in the source material and the predominant grain size of the material. This means of contaminant transport appears to be relatively insignificant in the Galena Creek drainage because of the relatively coarse grain size exhibited by the source materials and because of relatively high moisture contents in sampled material.
- ◆ Direct Contact -- Contaminant source materials are subject to transport through human action. This is most commonly performed through physical removal and transport. Such incidences are not common in the Hughesville/Barker Mining District and are probably not a significant means of contaminant transport in the area.

7.1.4 Receptors

Two general types of receptors are present in the Galena Creek drainage. These include human receptors and environmental receptors. It is not the intention of the AMR program to evaluate risks to human health from site contaminants. Data to support a human health assessment for the Hughesville/Barker Mining District were not collected during this PA.

The primary environmental receptors of site contaminants are Galena Creek and the Dry Fork of Belt Creek. The impact of contaminant sources on these streams was partially quantified during this PA.

The degree of impact and type of impact to the streams varies in accordance with stream conditions in the area. A chronic metals problem is evident in the stream during low flow and baseflow conditions. Such impacts are primarily derived from input of metals-laden groundwater from different source areas.

Acute impacts to the streams are realized during either precipitation- or snowmelt-induced runoff events. The impact of such events on the quality of water in Galena Creek and the Dry Fork of Belt Creek is different. Higher flow events and associated runoff conditions cause erosion and sedimentation to occur. Such conditions increase metals loading in the streams although metals concentrations may be lower than during baseflow conditions.

The resulting impact to the area's surface water system from both chronic and acute problems is a reduction in the diversity and vigor of the aquatic community and fisheries. Such an impact has been measured for several miles down the Dry Fork of Belt Creek below its confluence with Galena Creek. Use of Galena Creek and portions of the Dry Fork of Belt Creek for other purposes (e.g. drinking water supply, irrigation, recreation) has also been impacted.

7.1.5 Site Problems

Several environmental problems in the Galena Creek drainage were identified during this PA. These include:

- ◆ Metals-laden groundwater enters Galena Creek, particularly in the vicinity of the Block P Mine and dump. This input deleteriously impacts Galena Creek water quality. The source of this groundwater input appears to be associated with the underground mine workings of the Block P Mine.
- ◆ Metals-laden groundwater is present below the Block P Mill tailings impoundments. This water moves to the south and either directly enters Dry Fork of Belt Creek and Galena Creek or enters the Dry Fork at some point below the confluence of the two streams.
- ◆ Many area mine waste rock dumps are positioned adjacent to and above Galena Creek. Precipitation and snowmelt runoff erodes these materials and transports metals-laden sediment into Galena Creek. Such occurrences deleteriously impact the quality of water in Galena Creek and the Dry Fork of Belt Creek. Increased sedimentation rates also probably occur during runoff events. The Block P Mine waste dump is the largest dump in the area and is located directly adjacent to Galena Creek. Its proximity to the stream makes this waste dump the most problematic dump with respect to erosional impacts on the stream.
- ◆ Portions of the Block P tailings impoundments are located within the floodplain of Galena Creek. Materials contained in these impoundments contain relatively high concentrations of metals which are readily solubilized in water. The impoundments are subject to erosion or possibly catastrophic failure in the event of a large flood. Ramifications of such an occurrence would likely result in the release of several tens of thousands of cubic yards of tailings into Galena Creek and the Dry Fork of Belt Creek.

- ◆ Streamside tailings are present along reaches of Galena Creek and the Dry Fork of Belt Creek. These deposits are located along the active floodplain of these streams and are subject to erosion and entrainment during moderately high flow events in the drainage basins. The tailings contain metals which are subject to solubilization by surface flow and can be transported in suspension. These deposits probably impact the quality of water in Galena Creek and the Dry Fork of Belt Creek during out-of-bank flow events.
- ◆ Acid mine drainage (AMD) emanating from abandoned underground mines in the area either directly or indirectly enters Galena Creek. The most prominent area in which AMD occurs is in the vicinity of the Liberty and Danny T Mines. The impact of AMD from these sources on quality of water in Galena Creek is probably minimal with respect to other inputs to the stream but is suspected to be greatest during low flow and baseflow conditions. Data collected during this PA indicate that AMD from the Moulton Mine in the upper reaches of Galena Creek causes increased metals levels in the receiving stream.

These problems collectively impact the primary receiving stream in the study area, Galena Creek, and the Dry Fork of Belt Creek below its confluence with Galena Creek. The impacts to the surface water courses primarily include elevated metals concentrations with respect to ambient water quality criteria and an artificially high rate of sedimentation.

7.2 OPERABLE UNITS

Based on the results from this PA, several operable units were identified within the study area. An operable unit is defined as a discrete action that comprises an incremental step toward comprehensively addressing site problems. The cleanup of a site can be divided into a number of operable units, depending on the complexity of the problems associated

with the site. Operable units may address geographical portions of a site, specific site problems, or initial phases of an action, or may consist of any set of actions performed over time or any actions that are concurrent but located in different parts of a site.

Based on information collected during this PA, contaminant sources identified in the Hughesville/Barker Mining District are best divided into operable units based on geography and problem types. We recommend dividing the study area into the following operable units:

- ◆ The Block P Mill Tailing Impoundments -- This operable unit would include the upper and lower tailing ponds, a buffer area on the east, north, and south sides of the deposits, and an area south of the impoundments to the confluence of Galena Creek and the Dry Fork of Belt Creek. This area represents an operable unit because the lower impoundment at the site is situated in the floodplain of Galena Creek and is subject to catastrophic failure during flood events. In addition, the groundwater contamination identified south of the impoundments is derived from the tailings ponds.
- ◆ The Block P Mine and Mine Waste Dump -- This operable unit would include the large mine waste dump at the site and the underground mine workings associated with the Block P and Wright-Edwards Mines. This area appears to exert the greatest impacts to surface water quality in the drainage during low flow and baseflow conditions. Large loads of metals enter Galena Creek in this area via groundwater inflow from the mine workings. Galena Creek also erodes the toe of the mine waste dump during relatively high stage conditions in the stream. Runoff erodes the mine waste dump and directly enters Galena Creek.
- ◆ Streamside Tailings -- These deposits represent a separate operable unit because concentrations of water extractable metals in the material is similar and the location of the deposits with respect to Galena Creek is comparable. Streamside tailings are visible along both certain reaches of Galena Creek and the reach of the Dry Fork of Belt Creek below its

confluence with Galena Creek. These deposits are subject to erosion and entrainment by Galena Creek during high flow events. The deposits represent an acute source of metals input to Galena Creek.

- ◆ Various Mine Waste Dumps and Associated AMD -- This operable unit would include all historical mines and associated mine waste dumps in the drainage area exclusive of the Block P Mine operable unit. Mines in this operable unit would include, but not be limited to the following:

- | | |
|----------------------|---------------|
| • Liberty | • Silver Bell |
| • Danny T | • St. Louis |
| • Marceline | • Defiance |
| • Wright/Edwards | • Dr. Kollach |
| • Queen of the Hills | • May & Edna |
| • Tiger | • Paragon |
| • Moulton | • Carter |
| | • Harrison |

Problems at mines included in this operable unit are associated with either acid mine drainage and/or erosion and entrainment of mine waste material. Because all these mines and mine waste dumps are located in the Galena Creek drainage and because the degree of impact to the quality of Galena Creek from any one site is unknown, it is logical to group these areas into one operable unit. If further evaluation of this operable unit is contemplated, it may be prudent to further prioritize reclamation activities at the mine sites within this operable unit.

Information collected during this PA suggest that, of these mines, the Wright/Edwards, Danny T, and Marceline Mines may exert the greatest impact to Galena Creek water quality. Further evaluation of the relative contribution from these various mine sites will be necessary to provide a better basis to prioritize reclamation efforts within this operable unit.

Prioritization of the foregoing operable units with respect to the sequencing of reclamation should be based on reclamation objectives established by the AMRB. If AMRB's objective is to eliminate or minimize environmental degradation caused by the various contaminant sources in the Galena Creek drainage, it follows that the sequence in which operable units are reclaimed should be:

- (1) Block P Mill Tailings Operable Unit.
- (2) Block P Mine and Waste Dump Operable Unit
- (3) Streamside Tailings Operable Unit.
- (4) Abandoned Mine and Waste Dump Operable Unit.

The rationale for sequencing the operable units in this order is in the degree of environmental impact associated with each operable unit or the potential for impact to the environment by an operable unit. The Block P Mill tailings ranks highest on the priority list because of the potential for catastrophic failure of the lower impoundment and the subsequent release of large quantities of metals-laden sediments. Such an occurrence would obviously impact a large portion of the Dry Fork of Belt Creek and possibly Belt Creek. In the event of such a catastrophe, other environmental problems in the Galena Creek drainage would become relatively insignificant.

The Block P Mine and associated waste dump was ranked second on the priority list because of the chronic impact this area exerts on water quality in Galena Creek and the Dry Fork of Belt Creek. During most flow conditions in the streams, the majority of metals loads are derived from this source.

The streamside tailings operable unit and the abandoned mines operable unit may rank equally on the priority list for reclamation. This is because the relative impact on the environment from each operable unit is unknown, given the current understanding of the Galena Creek drainage. The impact from each operable unit may become more discernible if and when the two top ranking operable units are reclaimed. A decision as

to which of these two operable units to address first may best be accommodated by delaying the decision until determinations of the relative significance of environmental impacts from these operable units are made.

If the AMRB elects to formulate other objectives for reclamation of the Galena Creek drainage, the order in which operable units in the area are carried forward in the AMRB reclamation process may be altered.

8.0 REFERENCES CITED

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APPENDIX A
SURFACE WATER QUALITY DATA BASE

HUGHESVILLE SURFACE WATER QUALITY DATA

Physical Properties

Station	Sample Type	Sample Date	Sample Time	Lab Number	Sampling Method	Water Temperature (C)	Field pH (s.u.)	Lab pH (s.u.)	Field SC (umhos/cm)	Lab SC (umhos/cm)	Flow (cfs)	TDS (mg/l)	Sodium Adsorption Ratio
DF-01	BFS	10/17/90	1520	108721	EDI					2100		1600	6.11
DF-01	D	10/17/90	1230	108730	EDI	0.5	5.9	5.7	440	445	0.680	398	0.33
DF-01	LD	10/30/90		108730				5.5				420	R
DF-01	N	10/17/90	1220	108731	EDI	0.5	5.9	5.7	440	440	0.680	350	R
DF-01	XC	10/17/90	1410	108719	EDI	16.0	5.2	5.6	2	2	0.680	10	U
DF-02	N	10/16/90	1615	108727	EDI	3.0	5.7	6.6	292	205	0.030	162	R
DF-03	N	10/17/90	1000	108729	GRAB	3.0	2.9	3.1	2176	1770	0.004	1790	R
DF-04	BFS	10/18/90	1540	108720	EDI			9.2		2100		1610	6.12
DF-04	D	10/18/90	1340	108736	EDI	4.0	6.2	6.1	432	420	0.390	365	0.34
DF-04	N	10/16/90	1330	108735	EDI	4.0	6.1	6.1	440	410	0.390	353	R
DF-04	XC	10/18/90	1450	108716	EDI	16.0	5.2	6.7	2	2	0.390	10	U
DF-05	N	10/16/90	1045	108722	EDI	3.0	6.4	6.6	345	360	0.400	292	0.34
DF-07	N	10/16/90	1200	108726	EDI	3.0	7.1	7.9	291	280	0.310	222	0.10
DF-08	N	10/15/90	1710	108733	GRAB	4.0	7.1	7.3	288	310	0.090	235	0.12
DF-14	LD	10/30/90		108725				8.2		300			
DF-14	N	10/15/90	1600	108725	GRAB	5.0	7.7	8.0	288	300	0.320	208	0.09
DF-21	N	10/17/90	1440	108717	EDI	4.0	6.9	6.9	363	370	1.340	300	0.36
DF-22	N	10/17/90	1330	108718	EDI	4.0	7.9	8.0	195	190	4.210	113	R
DF-40	N	10/17/90	1535	108715	EDI	3.5	7.9	7.8	256	245	7.920	160	R
DF-45	N	10/15/90	1830	108734	GRAB	4.0	7.1	7.3	551	480	0.002	407	0.42
DF-46	N	10/16/90	1710	108728	EDI	3.0	7.4	5.7	493	450	0.510	396	R
DF-47	N	10/17/90	1125	108723	EDI	0.0	5.5	5.2	466	470	0.737	432	0.39
DF-49	N	10/15/90	1500	108732	GRAB	4.0	5.6	7.2	305	330	0.130	246	R

Notes: 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; N - Natural; XC - Cross Contamination Blank.

2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; C - Cross contamination blank equal to or above detection limit; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - Value not usable for statistics.

3) Blank values indicate parameters not determined.

4) Sampling Methods are defined as: EDI - Equal Discharge Interval; Grab - Grab Sample.

HUGHESVILLE SURFACE WATER DATA
Metals Data

Station	Sample Type	Sample Date	Sample Time	Aluminum Total (mg/l)	Aluminum Dissolved (mg/l)	Arsenic Total (mg/l)	Arsenic Dissolved (mg/l)	Barium Total (mg/l)	Barium Dissolved (mg/l)	Cadmium Total (mg/l)	Cadmium Dissolved (mg/l)
DF-01	BFS	10/17/90	1520	0.3	0.3	0.120	0.100	0.1	0.2	0.1040	0.0980
DF-01	D	10/17/90	1230	7.0	0.3	0.028	0.002	0.1	0.1	0.0500	0.0440
DF-01	LD	10/30/90		6.9	0.3	0.030	0.002	0.1	0.1	0.0520	0.0440
DF-01	N	10/17/90	1220	7.5	0.6	0.027	0.002	0.1	0.1	0.0530	0.0440
DF-01	XCB	10/17/90	1410	0.1	0.1	0.002	0.002	0.1	0.1	0.0001	0.0001
DF-02	N	10/16/90	1615	1.4	0.6	0.002	0.002	0.1	0.1	0.0141	0.0140
DF-03	N	10/17/90	1000	10.5	9.9	0.026	0.022	0.1	0.1	0.2600	0.2600
DF-04	BFS	10/18/90	1540	0.3	0.3	0.110	0.110	0.1	0.1	0.0980	0.0980
DF-04	D	10/18/90	1340	4.0	0.2	0.015	0.002	0.1	0.1	0.0320	0.0270
DF-04	N	10/16/90	1330	3.3	0.2	0.017	0.002	0.1	0.1	0.0350	0.0320
DF-04	XCB	10/18/90	1450	0.1	0.1	0.002	0.002	0.1	0.1	0.0001	0.0001
DF-05	N	10/16/90	1045	1.1	0.1	0.006	0.002	0.1	0.1	0.0114	0.0082
DF-07	N	10/16/90	1200	0.1	0.1	0.002	0.002	0.1	0.1	0.0008	0.0008
DF-08	N	10/15/90	1710	0.1	0.1	0.002	0.002	0.1	0.1	0.0024	0.0019
DF-14	LD	10/30/90		0.1	0.1	0.002	0.002	0.1	0.1	0.0002	0.0002
DF-14	N	10/15/90	1600	0.1	0.1	0.008	0.002	0.1	0.1	0.0005	0.0001
DF-21	N	10/17/90	1440	3.3	0.1	0.022	0.002	0.1	0.1	0.0300	0.0200
DF-22	N	10/17/90	1330	0.1	0.1	0.002	0.002	0.1	0.1	0.0001	0.0001
DF-40	N	10/17/90	1535	0.7	0.1	0.005	0.002	0.1	0.1	0.0068	0.0038
DF-45	N	10/15/90	1830	0.3	0.1	0.106	0.008	0.1	0.1	0.0125	0.0072
DF-46	N	10/16/90	1710	4.2	0.7	0.002	0.002	0.1	0.1	0.0450	0.0440
DF-47	N	10/17/90	1125	4.4	1.8	0.027	0.002	0.1	0.1	0.0500	0.0480
DF-49	N	10/15/90	1500	0.1	0.1	0.021	0.005	0.1	0.1	0.0002	0.0001

Notes: 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; N - Natural; XCB - Cross Contamination Blank.
2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; C - Cross contamination blank equal to or above detection limit; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - Value not usable for statistics.
3) Blank values indicate parameters not determined.
4) Sampling Methods are defined as: EDI - Equal Discharge Interval; Grab - Grab Sample.

HUGHESVILLE SURFACE WATER DATA
Metals Data

Station	Sample Type	Sample Date	Sample Time	Chromium Total (mg/l)	Chromium Dissolved (mg/l)	Copper Total (mg/l)	Copper Dissolved (mg/l)	Iron Total (mg/l)	Iron Dissolved (mg/l)	Lead Total (mg/l)	Lead Dissolved (mg/l)
DF-01	BFS	10/17/90	1520	0.195	0.165	0.26	0.26	0.14	0.14	0.150	0.150
DF-01	D	10/17/90	1230	0.004	C	0.21	0.06	26.20	3.85	0.210	0.001 U
DF-01	LD	10/30/90		0.003	C	0.20	0.06	26.50	4.20	0.215	0.001 U
DF-01	N	10/17/90	1220	0.003	C	0.20	0.07	26.70	3.91	0.200	0.010
DF-01	XCB	10/17/90	1410	0.001	C	0.02	U	0.05	U	0.001	U
DF-02	N	10/16/90	1615	0.002	C	0.05	0.04	1.15	0.06	0.053	0.034
DF-03	N	10/17/90	1000	0.010	C	0.70	0.70	130.00	128.00	0.110	0.102
DF-04	BFS	10/18/90	1540	0.195	0.165	0.26	0.26	0.14	0.14	0.150	0.150
DF-04	D	10/18/90	1340	0.002	U	0.11	0.02	17.90	11.20	0.037	0.001 U
DF-04	N	10/16/90	1330	0.002	C	0.11	0.03	18.30	11.90	0.038	0.001 U
DF-04	XCB	10/18/90	1450	0.001	U	0.02	0.02	0.05	0.05	0.001	U
DF-05	N	10/16/90	1045	0.002	U	0.04	0.02	8.61	0.98	0.029	0.001 U
DF-07	N	10/16/90	1200	0.001	U	0.02	0.02	0.32	0.06	0.003	0.001 U
DF-08	N	10/15/90	1710	0.001	U	0.02	0.02	0.17	0.05	0.008	0.001 U
DF-14	LD	10/30/90				0.02	0.02	0.69	0.05	0.001	U
DF-14	N	10/15/90	1600	0.002	U	0.02	0.02	0.78	0.05	0.002	0.001 U
DF-21	N	10/17/90	1440	0.003	C	0.16	0.02	16.60	0.06	0.155	0.001 U
DF-22	N	10/17/90	1330	0.001	C	0.02	0.02	0.08	0.05	0.001	U
DF-40	N	10/17/90	1535	0.004	C	0.04	0.02	2.92	0.05	0.014	0.001 U
DF-45	N	10/15/90	1830	0.001	U	0.02	0.02	8.97	0.07	0.017	0.001 U
DF-46	N	10/16/90	1710	0.003	C	0.19	0.06	21.80	13.60	0.046	0.002
DF-47	N	10/17/90	1125	0.004	U	0.19	0.16	24.10	7.08	0.195	0.043
DF-49	N	10/15/90	1500	0.003	C	0.02	0.02	1.79	0.05	0.001	U

- Notes: 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; N - Natural; XCB - Cross Contamination Blank.
2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; C - Cross contamination blank equal to or above detection limit; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - Value not usable for statistics.
3) Blank values indicate parameters not determined.
4) Sampling Methods are defined as: EDI - Equal Discharge Interval; Grab - Grab Sample.

HUGHESVILLE SURFACE WATER DATA
Metals Data

Station	Sample Type	Sample Date	Sample Time	Manganese Total (mg/l)	Manganese Dissolved (mg/l)	Mercury Total (mg/l)	Mercury Dissolved (mg/l)	Nickel Total (mg/l)	Nickel Dissolved (mg/l)	Selenium Total (mg/l)	Selenium Dissolved (mg/l)
DF-01	N	10/17/90	1220	12.400 R	12.400 CR	0.0002 U	0.0002 U	0.012	0.011	0.005 U	0.005 U
DF-01	D	10/17/90	1230	12.100 R	12.100 CR	0.0002 U	0.0002 U	0.017	0.010	0.005 U	0.005 U
DF-01	XCB	10/17/90	1410	0.015 U	0.015 C	0.0002 U	0.0002 U	0.002 U	0.002 U	0.005 U	0.005 U
DF-01	BFS	10/17/90	1520	0.170	0.170	0.0046	0.0046	0.380	0.380	0.087	0.087
DF-40	N	10/17/90	1535	1.990 R	1.990 CR	0.0002 U	0.0002 U	0.007	0.002 U	0.005 U	0.005 U
DF-22	N	10/17/90	1330	0.064 R	0.064 CR	0.0002 U	0.0002 U	0.002 U	0.002 U	0.005 U	0.005 U
DF-21	N	10/17/90	1440	7.150 R	7.150 CR	0.0002 U	0.0002 U	0.010	0.006	0.005 U	0.005 U
DF-49	N	10/15/90	1500	0.314 R	0.311 CR	0.0002 U	0.0002 U	0.017	0.003	0.005 U	0.005 U
DF-03	N	10/17/90	1000	129.000 R	128.000 CR	0.0002 U	0.0002 U	0.150	0.130	0.005 U	0.005 U
DF-02	N	10/16/90	1615	2.040 R	2.040 CR	0.0002 U	0.0002 U	0.020	0.002 U	0.005 U	0.005 U
DF-46	N	10/16/90	1710	13.100 R	13.100 CR	0.0002 U	0.0002 U	0.017	0.010	0.005 U	0.005 U
DF-04	N	10/16/90	1330	7.560 R	7.560 CR	0.0002 U	0.0002 U	0.013	0.008	0.005 U	0.005 U
DF-04	BFS	10/18/90	1540	0.160	0.160	0.0047	0.0047	0.350	0.350	0.093	0.090
DF-04	XCB	10/18/90	1450	0.015 U	0.015 U	0.0002 U	0.0002 U	0.002 U	0.002 U	0.005 U	0.005 U
DF-04	D	10/18/90	1340	8.400	8.400	0.0002 U	0.0002 U	0.017	0.006	0.005 U	0.005 U
DF-05	N	10/16/90	1045	5.280	5.280	0.0002 U	0.0002 U	0.006	0.002	0.005 U	0.005 U
DF-45	N	10/15/90	1830	7.290	7.290	0.0002 U	0.0002 U	0.006	0.002	0.005 U	0.005 U
DF-08	N	10/15/90	1710	0.410	0.410	0.0002 U	0.0002 U	0.003	0.002 U	0.005 U	0.005 U
DF-07	N	10/16/90	1200	0.230	0.230	0.0002 U	0.0002 U	0.002 U	0.002 U	0.005 U	0.005 U
DF-14	N	10/15/90	1600	0.212	0.173	0.0002 U	0.0002 U	0.004	0.002 U	0.005 U	0.005 U
DF-47	N	10/17/90	1125	13.400	10.600	0.0002 U	0.0002 U	0.016	0.006	0.005 U	0.005 U
DF-14	LD	10/30/90		0.190	0.180			0.007	0.006	0.005 U	0.005 U
DF-01	LD	10/30/90		12.000 R	12.100 CR	0.0002 U	0.0002 U	0.016	0.008	0.005 U	0.005 U

- Notes: 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; N - Natural; XCB - Cross Contamination Blank.
2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; C - Cross contamination blank equal to or above detection limit; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - Value not usable for statistics.
3) Blank values indicate parameters not determined.
4) Sampling Methods are defined as: EDI - Equal Discharge Interval; Grab - Grab Sample.

HUGHESVILLE SURFACE WATER DATA
Metals Data

Station	Sample Type	Sample Date	Sample Time	Silver Total (mg/l)	Silver Dissolved (mg/l)	Zinc Total (mg/l)	Zinc Dissolved (mg/l)
DF-01	N	10/17/90	1220	0.0009	A	11.90	R
DF-01	D	10/17/90	1230	0.0009	A	11.30	R
DF-01	XCB	10/17/90	1410	0.0001	U	0.02	U
DF-01	BFS	10/17/90	1520	0.0430	0.0390	0.20	0.20
DF-40	N	10/17/90	1535	0.0018	A	1.08	R
DF-22	N	10/17/90	1330	0.0001	UA	0.05	UR
DF-21	N	10/17/90	1440	0.0006	A	6.30	R
DF-49	N	10/15/90	1500	0.0001	UA	0.09	R
DF-03	N	10/17/90	1000	0.0003	A	65.00	R
DF-02	N	10/16/90	1615	0.0001	UA	2.55	R
DF-46	N	10/16/90	1710	0.0004	A	11.00	
DF-04	N	10/16/90	1330	0.0070	A	7.44	7.35
DF-04	BFS	10/18/90	1540	0.0390	0.0350	0.19	0.19
DF-04	XCB	10/18/90	1450	0.0001	U	0.02	U
DF-04	D	10/18/90	1340	0.0005	A	7.52	7.48
DF-05	N	10/16/90	1045	0.0002	A	2.95	2.71
DF-45	N	10/15/90	1830	0.0001	UA	2.03	1.45
DF-08	N	10/15/90	1710	0.0001	UA	0.50	0.51
DF-07	N	10/16/90	1200	0.0001	UA	0.24	0.23
DF-14	N	10/15/90	1600	0.0004	A	0.09	0.04
DF-47	N	10/17/90	1125	0.0008	A	11.90	11.90
DF-14	LD	10/30/90		A	A	0.08	0.05
DF-01	LD	10/30/90		0.0009	A	11.20	11.60

- Notes: 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; N - Natural; XCB - Cross Contamination Blank.
- 2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; C - Cross contamination blank equal to or above detection limit; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - Value not usable for statistics.
- 3) Blank values indicate parameters not determined.
- 4) Sampling Methods are defined as: EDI - Equal Discharge Interval; Grab - Grab Sample.

HUGHESVILLE SURFACE WATER DATA

Anions Data

Station	Sample Type	Sample Date	Sample Time	Total Alkalinity as CaCO ₃ (mg/l)	Bicarbonate Alkalinity as HCO ₃ (mg/l)	Carbonate Alkalinity as CO ₃ (mg/l)	Hydroxide Alkalinity as OH (mg/l)	Chloride as Cl (mg/l)	Fluoride as F (mg/l)	Nitrate + Nitrite as N (mg/l)	Sulfate as SO ₄ (mg/l)
DF-01	BFS	10/17/90	1520	203	248	0	0	328	15.80	4.80	340
DF-01	D	10/17/90	1230	4	5	0	0	1	0.55	0.05	252
DF-01	LD	10/30/90		4		0	0	1	U	0.05	U
DF-01	N	10/17/90	1220	5	6	0	0	1	0.59	0.05	253
DF-01	XCB	10/17/90	1410	5	6	0	0	1	0.05	0.05	1
DF-02	N	10/16/90	1615	14	17	0	0	1	0.28	0.05	97
DF-03	N	10/17/90	1000	1	1	0	0	1	1.57	0.20	1260
DF-04	BFS	10/18/90	1540	211	258	0	0	334	14.10	4.84	337
DF-04	D	10/18/90	1340	14	17	0	0	1	0.45	0.05	230
DF-04	N	10/16/90	1330	16	20	0	0	1	0.45	0.05	226
DF-04	XCB	10/18/90	1450	10	12	0	0	1	0.05	0.05	2
DF-05	N	10/16/90	1045	56	68	0	0	1	0.36	0.05	152
DF-07	N	10/16/90	1200	83	101	0	0	1	0.19	0.05	90
DF-08	N	10/15/90	1710	38	46	0	0	1	0.18	0.05	137
DF-14	LD	10/30/90				0	0		0.21	0.05	U
DF-14	N	10/15/90	1600	122	149	0	0	1	0.21	0.05	57
DF-21	N	10/17/90	1440	45	55	0	0	1	0.33	0.05	166
DF-22	N	10/17/90	1330	107	131	0	0	1	0.07	0.05	7
DF-40	N	10/17/90	1535	91	111	0	0	1	0.10	0.05	50
DF-45	N	10/15/90	1830	71	87	0	0	1	2.15	0.09	220
DF-46	N	10/16/90	1710	6	7	0	0	1	0.53	0.05	266
DF-47	N	10/17/90	1125	2	2	0	0	1	0.59	0.05	276
DF-49	N	10/15/90	1500	141	172	0	0	1	0.30	0.05	60

Notes: 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; N - Natural; XCB - Cross Contamination Blank.

2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; C - Cross contamination blank equal to or above detection limit; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - Value not usable for statistics.

3) Blank values indicate parameters not determined.

4) Sampling Methods are defined as: EDI - Equal Discharge Interval; Grab - Grab Sample.

HUGHESVILLE SURFACE WATER DATA

Cations Data

Station	Sample Type	Sample Date	Sample Time	Total Hardness as CaCO ₃ (mg/l)	Calcium as Ca (mg/l)	Magnesium as Mg (mg/l)	Potassium as K (mg/l)	Sodium as Na (mg/l)
DF-01	N	10/17/90	1220	243	66	19	1	11
DF-01	D	10/17/90	1230	253	70	19	1	12
DF-01	XCB	10/17/90	1410	7	1	1	1	4
DF-01	BFS	10/17/90	1520	565	139	53	268	334
DF-40	N	10/17/90	1535	149	43	10	1	2
DF-22	N	10/17/90	1330	121	35	8	1	2
DF-21	N	10/17/90	1440	204	57	15	1	12
DF-49	N	10/15/90	1500	216	45	25	1	4
DF-03	N	10/17/90	1000	631	172	49	1	25
DF-02	N	10/16/90	1615	104	35	4	1	9
DF-46	N	10/16/90	1710	261	70	21	1	12
DF-04	N	10/16/90	1330	240	65	19	1	12
DF-04	BFS	10/18/90	1540	560	137	53	268	333
DF-04	XCB	10/18/90	1450	7	1	1	1	4
DF-04	D	10/18/90	1340	238	64	19	1	12
DF-05	N	10/16/90	1045	198	53	16	1	11
DF-45	N	10/15/90	1830	282	85	17	1	16
DF-08	N	10/15/90	1710	187	52	14	1	4
DF-07	N	10/16/90	1200	182	48	15	1	3
DF-14	N	10/15/90	1600	192	47	18	1	3
DF-47	N	10/17/90	1125	247	66	20	1	14
DF-14	LD	10/30/90			48	18	1	4
DF-01	LD	10/30/90			65	18	1	16

- Notes:
- 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; N - Natural; XCB - Cross Contamination Blank.
 - 2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; C - Cross contamination blank equal to or above detection limit; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - Value not usable for statistics.
 - 3) Blank values indicate parameters not determined.
 - 4) Sampling Methods are defined as: EDI - Equal Discharge Interval; Grab - Grab Sample.

APPENDIX B
GROUNDWATER

APPENDIX B-1

MONITORING WELL LITHOLOGIC AND COMPLETION LOGS

[illegible]

MONITORING WELL LITHOLOGIC AND COMPLETION LOG

JOB NO.: 90-3133J

PROJECT: Hughesville STATE: MT COUNTY: Cascade WELL NO.: HMW-2

LEGAL	DESCRIPTIVE
LOCATION: T 15N R 8E S 13 TRACT DCA	<u>Downgradient of Block P tailings</u>
	LOCATION: -30' SE of Amax well

DATE STARTED: 11-8-90 DATE COMPLETED: 11-8-90 DRILLING COMPANY/ DRILLER: H & L/Mark LOGGED BY: Dunlavy

DRILLING METHOD: Air Rotary BOREHOLE DIAMETER (In): 5 7/8" DRILL FLUIDS USED: Air

TOTAL DEPTH DRILLED (ft): 10	TOTAL DEPTH CASED (ft): 8	INTERVAL PERFORATED OR SCREENED (ft):	from: 3 to: 8	DIAMETER AND 2" Flush Threaded TYPE OF CASING: PVC
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METHOD OF PERFORATION:		DURING WELL CONSTRUCTION WAS/WERE:	
<input type="checkbox"/>	Open Hole	<input type="checkbox"/>	YES
<input type="checkbox"/>	Open Bottom	<input type="checkbox"/>	NO
<input type="checkbox"/>	Saw Slotted	<input checked="" type="checkbox"/>	WELL DEVELOPED
<input checked="" type="checkbox"/>	Factory 0.020 (size)	<input type="checkbox"/>	WELL PUMPED
<input type="checkbox"/>	OTHER (specify) _____	<input type="checkbox"/>	WATER SAMPLES COLLECTED
		<input type="checkbox"/>	MATERIAL SAMPLES COLLECTED

ANNULAR COMPLETION CHARACTERISTICS

WELL PROTECTOR: Length 3' Diam. 6" SURFACE SEAL: Type: Concrete from: 0.0 to: +1.0
 LOCK NO.: 2265 BACKFILL: Material: Holeplug from: 2.5 to: 0.0
 FILTER PACK: Type: 10-20 CSSI from: 8 to: 2.5

STATIC WATER LEVEL: 6.53	MEASURING POINT DATE: 11/26/90	DESCRIPTION/ ELEVATION: Top of steel, N. side	MEASURING POINT RELATIVE TO GROUND SURFACE (+/-):
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REMARKS: S.W.L. in Amax well = 6.9 feet below PVC; 2' stick-up

[illegible]

MONITORING WELL LITHOLOGIC AND COMPLETION LOG

JOB NO.: 90-3133J

PROJECT: Hughesville STATE: MT COUNTY: Cascade WELL NO.: HMW-3

LEGAL	DESCRIPTIVE
LOCATION: T15N R8E S13 TRACT DAA	Upgradient of Block P tailings LOCATION: 30' west of road

DATE STARTED: 11-8-90 DATE COMPLETED: 11-8-90 DRILLING COMPANY/
DRILLER: H & L/Mark LOGGED BY: Dunlavy

DRILLING METHOD: Air Rotary

TOTAL DEPTH DRILLED (ft): 60	TOTAL DEPTH CASED (ft): 22	INTERVAL PERFORATED OR SCREENED (ft):	from: 12 to: 22	DIAMETER AND 2" Flush Threaded TYPE OF CASING: Sch 40 PVC
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METHOD OF PERFORATION: _____		DURING WELL CONSTRUCTION WAS/WERE:	
_____	Open Hole	YES	NO
_____	Open Bottom	_____	_____
_____	Saw Slotted	_____	_____
<u>X</u>	Factory _____ 0.020 (size)	WELL DEVELOPED	<u>X</u>
_____	OTHER (specify) _____	WELL PUMPED	<u>X</u>
		WATER SAMPLES COLLECTED	<u>X</u>
		MATERIAL SAMPLES COLLECTED	<u>X</u>

ANNULAR COMPLETION CHARACTERISTICS

WELL PROTECTOR: Length <u>5'</u>	Diam. <u>6"</u>	SURFACE SEAL: Type: <u>Concrete</u>	from: <u>2.0</u>	to: <u>0.0</u>
LOCK NO.: <u>2265</u>		BACKFILL: Material: <u>Holeplug</u>	from: <u>60-22</u>	and: <u>8-2.0</u>
		FILTER PACK: Type: <u>10-20 CSSI</u>	from: <u>22</u>	to: <u>8</u>

STATIC WATER LEVEL: 12.62	MEASURING POINT DATE: 11/28/90	DESCRIPTION/ ELEVATION: Top of steel, N. side	MEASURING POINT RELATIVE TO GROUND SURFACE (+/-):
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REMARKS: Backfilled open hole (22-60) with holeplug bentonite

[illegible]

[illegible]

JOB NO.: 90-3133J

PROJECT: Hughesville STATE: MT COUNTY: Judith Basin WELL NO.: HMW-5

DATE STARTED: 11-7-90 DATE COMPLETED: 11-7-90 DRILLING COMPANY/ DRILLER: H & L/Mark LOGGED BY: Dunlavy

TOTAL DEPTH DRILLED (ft): 116	TOTAL DEPTH CASED (ft): 112.5	INTERVAL PERFORATED OR SCREENED (ft):	from: <u>107.5</u> to: <u>87.5</u>	DIAMETER AND 4" Flush Threaded TYPE OF CASING: Sch 40 PVC
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ANNULAR COMPLETION CHARACTERISTICS				
WELL PROTECTOR: Length	5'	Diam.	6"	
LOCK NO.:	2265	SURFACE SEAL: Type:	Concrete	
		BACKFILL: Material:	Holeplug	
		FILTER PACK: Type:	10-20 CSSI	
			from: 2.0'	to: 0.0'
			from: 85'	to: 2.0'
			from: 116	to: 85'

STATIC WATER LEVEL: 83.9'	MEASURING POINT DATE: 11-8-90	DESCRIPTION/ ELEVATION: Top of PVC N. Side	MEASURING POINT RELATIVE TO GROUND SURFACE (+/-):
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[illegible]

JOB NO.: 90-3133J

PROJECT: Hughesville STATE: MT COUNTY: Judith Basin WELL NO.: HMW-6

DATE STARTED: 11-6-90 DATE COMPLETED: 11-6-90 DRILLING COMPANY/DRILLER: H & L/Mark LOGGED BY: D. Hazen

TOTAL DEPTH DRILLED (ft): <u>18</u>	TOTAL DEPTH CASED (ft): <u>18</u>	INTERVAL PERFORATED OR SCREENED (ft):	from: <u>13</u> to: <u>18</u>	DIAMETER AND 2" PVC Sch 40 TYPE OF CASING: _____
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ANNULAR COMPLETION CHARACTERISTICS		Material: <u>Concrete</u>	from: <u>2.0</u>	to: <u>0.0</u>
WELL PROTECTOR: Length <u>8'</u>	Diam. <u>6"</u>	SURFACE SEAL: Material: <u>Cuttings</u>	from: <u>6.0</u>	to: <u>0.0</u>
LOCK NO.: <u>2265</u>		BACKFILL: Material: <u>Holeplug Bent</u>	from: <u>11.5</u>	to: <u>6.0</u>
		Material: _____	from: _____	to: _____
		FILTER PACK: Type: <u>10-20 CSSI</u>	from: <u>18</u>	to: <u>11.5</u>

STATIC WATER LEVEL: 5.32	MEASURING POINT DATE: 11/26/90	DESCRIPTION/ ELEVATION: Top of PVC, N. side	MEASURING POINT RELATIVE TO GROUND SURFACE (+/-):
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REMARKS: _____

[illegible]

MONITORING WELL LITHOLOGIC AND COMPLETION LOG

JOB NO.: 90-3133J

PROJECT: Hughesville STATE: MT COUNTY: Judith Basin WELL NO.: HMW-7

LEGAL LOCATION: T 15N R 9E S 6 TRACT DCA DESCRIPTIVE At base of Block P Dump
LOCATION: _____

DATE STARTED: 11-6-90 DATE COMPLETED: 11-6-90 DRILLING COMPANY/ DRILLER: _____ LOGGED BY: D. Hazen

DRILLING METHOD: Hand, Drive Point BOREHOLE DIAMETER (In): 1 1/4 DRILL FLUIDS USED: None

TOTAL DEPTH DRILLED (ft): <u>3.5</u>	TOTAL DEPTH CASED (ft): <u>3.5</u>	INTERVAL PERFORATED OR SCREENED (ft):	from: <u>0.5</u> to: <u>3.5</u>	DIAMETER AND 1" PVC TYPE OF CASING: _____
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METHOD OF PERFORATION:		DURING WELL CONSTRUCTION WAS/WERE:	
<input type="checkbox"/>	Open Hole	YES	NO
<input checked="" type="checkbox"/>	Open Bottom	<input checked="" type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	Saw Slotted	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/>	Factory _____ (size) 0.020	WELL DEVELOPED	<input type="checkbox"/>
<input type="checkbox"/>	OTHER (specify) _____	WELL PUMPED	<input type="checkbox"/>
		WATER SAMPLES COLLECTED	<input type="checkbox"/>
		MATERIAL SAMPLES COLLECTED	<input checked="" type="checkbox"/>

ANNULAR COMPLETION CHARACTERISTICS

WELL PROTECTOR: Length <u>3.0</u>	Diam. <u>6"</u>	SURFACE SEAL: Type: _____	from: _____	to: _____
LOCK NO.: <u>2265</u>		BACKFILL: Material: <u>Native</u>	from: <u>0.0</u>	to: <u>0.5</u>
		FILTER PACK: Type: <u>Native</u>	from: <u>0.5</u>	to: <u>3.5</u>

STATIC WATER LEVEL: 3.85	MEASURING POINT DATE: 11/26/90	DESCRIPTION/ ELEVATION: Top of PVC, N. side	MEASURING POINT RELATIVE TO GROUND SURFACE (+/-):
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REMARKS: _____

[illegible]

JOB NO.: 90-3133J

PROJECT: Hughesville STATE: MT COUNTY: Judith Basin WELL NO.: HMW-8

DATE STARTED: 11-6-90 DATE COMPLETED: 11-6-90 DRILLING COMPANY/ DRILLER: H & L, Mark LOGGED BY: D. Hazen

TOTAL DEPTH TOTAL DEPTH INTERVAL PERFORATED from: 20 DIAMETER AND 2" PVC, Sch 40
 DRILLED (ft): 25 CASED (ft): 25 OR SCREENED (ft): to: 25 TYPE OF CASING:

ANNULAR COMPLETION CHARACTERISTICS			
WELL PROTECTOR: Length	<u>16.5</u>	Diam. <u>6"</u>	
LOCK NO.:	<u>2265</u>		
SURFACE SEAL: Type:	<u>Concrete</u>	from: <u>1.0</u>	to: <u>+1.0</u>
BACKFILL: Material:	<u>Holeplug Bent</u>	from: <u>17</u>	to: <u>1.0</u>
FILTER PACK: Type:	<u>10-20 Colorado</u>	from: <u>25</u>	to: <u>17</u>

REMARKS: _____

[illegible]

APPENDIX B-2
GROUNDWATER QUALITY DATA BASE

HUGHESVILLE GROUNDWATER QUALITY DATA
Physical Properties

Station	Sample Type	Sample Date	Sample Time	Lab Number	Sampling Method	Water		Field pH (s.u.)	Lab pH (s.u.)	Field SC (umhos/cm)	Lab SC (umhos/cm)	TDS (mg/l)		Sodium Adsorption Ratio
						Temperature (C)								
AMAX-2	LD	11/30/90		109249					2.9		6130	8560		
AMAX-2	N	11/14/90	1650	109249	HLP	6.0	2.5	2.9	2.9	6280	6010	8460		0.28
HW-01	N	11/15/90	0900	109248	HLP	5.0	5.5	5.5	5.5	2385	2340	2410		0.13
HW-02	N	11/14/90	1615	109237	HLP	6.0	2.8	3.2	3.2	5480	5600	7930	R	0.32
HW-03	N	11/15/90	0950	109247	BAIL	4.0	7.5	8.0	8.0	1330	1250	822		6.09
HW-04	N	11/15/90	1100	109246	HLP	6.0	6.4	6.7	6.7	232	243	152		0.13
HW-05	N	11/14/90	0940	109242	BAIL	7.0	5.7	5.9	5.9	2004	2110	1860	R	0.41
HW-06	N	11/14/90	1300	109238	HLP	6.5	4.8	4.6	4.6	1782	2050	1540	R	0.34
HW-08	BFS	11/14/90	1115	109256	HLP			0.0	0.0		845			5.41
HW-08	D	11/14/90	1055	109240	HLP	7.0	5.1	5.1	5.1	918	1030	860	R	0.17
HW-08	LD	11/29/90		109240										
HW-08	N	11/14/90	1045	109241	HLP	7.0	5.1	5.1	5.1	918	1030	860	R	
HW-08	XCB	11/14/90	1105	109239	HLP	8.0	4.9	5.0	5.0	9	33	780	R	0.20
MCBRIDE	BFS	11/15/90	1330	109250	PUMP			9.0	9.0		880	1	U	0.16
MCBRIDE	D	11/15/90	1300	109244	PUMP	6.0	6.7	7.3	7.3	360	355	216		5.44
MCBRIDE	N	11/15/90	1245	109245	PUMP	5.5	6.6	7.1	7.1	348	359	216		0.06
MCBRIDE	XCB	11/15/90	1315	109243	PUMP	6.0	3.6	5.5	5.5	6	10	8	U	0.16

- Notes: 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; LD - Laboratory Duplicate; N - Natural; XCB - Cross Contamination Blank.
2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; C - Cross contamination blank equal to or above detection limit; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - Value not usable for statistics.
3) Blank values indicate parameters not determined.
4) Sampling Methods are defined as: Bail - Hand Bail; HLP - Hand Lift Pump; Pump - Domestic Pump.

HUGHESVILLE GROUNDWATER DATA
Dissolved Metals

Station	Sample Type	Sample Date	Sample Time	Aluminum (mg/l)	Arsenic (mg/l)	Barium (mg/l)	Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Iron (mg/l)	Lead (mg/l)
AMAX-2	LD	11/30/90		127.0	0.002	0.2	0.8270	0.240	13.00	1570.00	0.002
AMAX-2	N	11/14/90	1650	128.0	0.002	0.2	0.8300	0.230	13.00	1550.00	0.002
HW-01	N	11/15/90	0900	0.9	0.002	0.1	0.2270	0.002	0.08	166.00	0.001
HW-02	N	11/14/90	1615	87.0	0.002	0.3	1.0900	0.024	17.00	1260.00	0.030
HW-03	N	11/15/90	0950	0.1	0.002	0.1	0.0002	0.014	0.02	0.08	0.001
HW-04	N	11/15/90	1100	0.1	0.002	0.1	0.0013	0.014	0.02	0.05	0.001
HW-05	N	11/14/90	0940	0.9	0.069	0.1	0.1190	0.002	0.02	135.00	0.002
HW-06	N	11/14/90	1300	14.0	0.003	0.1	0.4400	0.007	1.64	143.00	0.066
HW-08	BFS	11/14/90	1115	0.2	0.088	0.2	0.1000	0.130	0.28	0.17	0.088
HW-08	D	11/14/90	1055	1.3	0.036	0.1	0.0950	0.002	0.02	78.00	0.800
HW-08	LD	11/29/90		1.4	0.036	0.1	0.0920	0.002	0.02	71.00	0.800
HW-08	N	11/14/90	1045	1.4	0.034	0.1	0.0960	0.002	0.02	70.00	0.860
HW-08	XCB	11/14/90	1105	0.1	0.002	0.1	0.0038	0.002	0.02	0.09	0.001
ACBRIDE	BFS	11/15/90	1330	0.2	0.088	0.2	0.1020	0.140	0.26	0.18	0.082
ACBRIDE	D	11/15/90	1300	0.1	0.002	0.1	0.0002	0.002	0.02	1.36	0.001
ACBRIDE	N	11/15/90	1245	0.1	0.002	0.1	0.0002	0.002	0.02	1.74	0.001
ACBRIDE	XCB	11/15/90	1315	0.1	0.002	0.1	0.0003	0.002	0.02	0.05	0.001

Notes: 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; LD - Laboratory Duplicate; N - Natural; XCB - Cross Contamination Blank.
2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; C - Cross contamination blank equal to or above detection limit; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - Value not usable for statistics.
3) Blank values indicate parameters not determined.
4) Sampling methods are defined as: Bail - Hand Bail; HLP - Hand Lift Pump; Pump - Domestic Pump.

HUGHESVILLE GROUNDWATER DATA
Dissolved Metals

Station	Sample Type	Sample Date	Sample Time	Manganese (mg/l)	Mercury (mg/l)	Nickel (mg/l)	Selenium (mg/l)	Silver (mg/l)	Zinc (mg/l)
AMAX-2	LD	11/30/90		490.00	A	0.61		0.0003	113.00
AMAX-2	N	11/14/90	1650	480.00	A	0.62	0.005	0.0002	113.00
HWW-01	N	11/15/90	0900	164.00	UA	0.31	0.005	0.0003	41.00
HWW-02	N	11/14/90	1615	320.00	CR	0.62	0.005	0.0015	110.00
HWW-03	N	11/15/90	0950	0.100	A	0.02	0.005	0.0001	0.02
HWW-04	N	11/15/90	1100	0.180	UA	0.02	0.005	0.0002	0.25
HWW-05	N	11/14/90	0940	86.000	CR	0.19	0.005	0.0010	58.00
HWW-06	N	11/14/90	1300	89.000	CR	0.18	0.005	0.0005	73.00
HWW-08	BFS	11/14/90	1115	0.170	0.0049	0.30	0.080	0.0400	0.20
HWW-08	D	11/14/90	1055	50.000	CR	0.09	0.005	0.0005	24.00
HWW-08	LD	11/29/90		46.000	CR	0.08	0.005	0.0004	23.00
HWW-08	N	11/14/90	1045	45.000	CR	0.12	0.005	0.0008	23.00
HWW-08	XCB	11/14/90	1105	0.030	0.0002	0.02	0.005	0.0006	0.02
MCBRIDE	BFS	11/15/90	1330	0.085	0.0070	0.39	0.088	0.0400	0.20
MCBRIDE	D	11/15/90	1300	0.180	UA	0.03	0.005	0.0012	0.04
MCBRIDE	N	11/15/90	1245	0.200	UA	0.04	0.005	0.0007	0.04
MCBRIDE	XCB	11/15/90	1315	0.020	0.0002	0.02	0.005	0.0070	0.02

- Notes: 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; LD - Laboratory Duplicate; N - Natural; XCB - Cross Contamination Blank.
2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; C - Cross contamination blank equal to or above detection limit; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - Value not usable for statistics.
3) Blank values indicate parameters not determined.
4) Sampling Methods are defined as: Ball - Hand Bailer; HLP - Hand Lift Pump; Pump - Domestic Pump.

HUGHESVILLE GROUNDWATER DATA
Anions Data

Station	Sample Type	Sample Date	Sample Time	Total Alkalinity as CaCO ₃ (mg/l)	Bicarbonate Alkalinity HCO ₃ (mg/l)	Carbonate Alkalinity CO ₃ (mg/l)	Hydroxide Alkalinity as OH (mg/l)	Chloride as Cl (mg/l)	Fluoride as F (mg/l)	Nitrate & Nitrite as N (mg/l)	Sulfate as SO ₄ (mg/l)
AMAX-2	LD	11/30/90		1	U	0	0	2	0.16	0.03	5860
AMAX-2	N	11/14/90	1650	1	U	0	0	2	0.14	0.03	5900
HW-01	N	11/15/90	0900	1	U	0	0	1	0.62	0.03	1690
HW-02	N	11/14/90	1615	1	U	0	0	1	0.18	0.03	4980
HW-03	N	11/15/90	0950	404	493	0	0	6	0.41	0.30	227
HW-04	N	11/15/90	1100	35	43	0	0	1	0.16	0.14	72
HW-05	N	11/14/90	0940	12	15	0	0	4	2.07	0.03	1390
HW-06	N	11/14/90	1300	1	1	0	0	2	0.62	0.04	1210
HW-08	BFS	11/14/90	1115	188	229	0	0	320	16.50	3.85	290
HW-08	D	11/14/90	1055	1	1	0	0	1	0.94	0.31	548
HW-08	LD	11/29/90		1	U	0	0	1	0.89	0.30	526
HW-08	N	11/14/90	1045	1	U	0	0	1	0.94	0.05	489
HW-08	XCB	11/14/90	1105	2	2	0	0	1	0.10	0.15	3
ACBR IDE	BFS	11/15/90	1330	201	245	0	0	325	16.50	3.80	310
ACBR IDE	D	11/15/90	1300	155	189	0	0	1	0.21	0.07	26
ACBR IDE	N	11/15/90	1245	162	198	0	0	1	0.20	0.03	22
ACBR IDE	XCB	11/15/90	1315	4	5	0	0	1	0.10	0.15	1

Notes: 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; LD - Laboratory Duplicate; N - Natural; XCB - Cross Contamination Blank.

2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; C - Cross contamination blank equal to or above detection limit; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - value not usable for statistics.

3) Blank values indicate parameters not determined.

4) Sampling Methods are defined as: Bail - Hand Bail; HLP - Hand Lift Pump; Pump - Domestic Pump.

HUGHESVILLE GROUNDWATER DATA
Cation Data

Station	Sample Type	Sample Date	Sample Time	Hardness as CaCO3 (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)
AMAX-2	LD	11/30/90			270	113	22	3
AMAX-2	N	11/14/90	1650	1183	276	120	22	3
FWW-01	N	11/15/90	0900	1087	310	76	10	3
FWW-02	N	11/14/90	1615	1302	327	118	27	4
FWW-03	N	11/15/90	0950	194	43	21	195	16
FWW-04	N	11/15/90	1100	104	25	10	3	1
FWW-05	N	11/14/90	0940	934	224	91	29	4
FWW-06	N	11/14/90	1300	775	205	64	22	2
FWW-08	BFS	11/14/90	1115	544	132	52	290	272
FWW-08	D	11/14/90	1055	315	85	25	7	2
FWW-08	LD	11/29/90			86	25	8	2
FWW-08	N	11/14/90	1045	311	85	24	8	2
FWW-08	XCB	11/14/90	1105	7	1	1	1	U
MCBRIDE	BFS	11/15/90	1330	537	131	51	290	272
MCBRIDE	D	11/15/90	1300	192	54	14	2	1
MCBRIDE	N	11/15/90	1245	197	56	14	2	1
MCBRIDE	XCB	11/15/90	1315	7	1	1	1	U

Notes: 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; LD - Laboratory Duplicate; N - Natural; XCB - Cross Contamination Blank.

2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; C - Cross contamination blank equal to or above detection limit; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - value not usable for statistics.

3) Blank values indicate parameters not determined.

4) Sampling methods are defined as: Bail - Hand Bail; HLP - Hand Lift Pump; Pump - Domestic Pump.

APPENDIX B-3
SLUG TEST DATA AND ANALYSES

DATA SET: HMW4IN

CLIENT: DSL/AMR	DATE: NOV 26,90
LOCATION: HUGHESVILLE, MT	WELL NO.: HMW-4
COUNTY: JUDITH BASIN COUNTY	WELL DEPTH: 18.00 ft
PROJECT: Well Slug Test Data	WATER TABLE: 4.480 ft
AQUIFER: ALLUVIUM	THICKNESS: 7.00 ft
WELL RADIUS: 0.320 ft	CASING RADIUS: 0.083 ft
SCREEN TOP: 5.000 ft	SCREEN BASE: 12.00 ft
INITIAL HEAD: 4.300 ft	TRANS. RATIO: 1.0000

MODEL PARAMETERS:

TRANSMISSIVITY: 130.03720square ft/day

CONDUCTIVITY: 18.57674 ft/day

WELL TYPE: UNCONFINED PARTIALLY PENETRATED AQUIFER (Bouwer & Rice)

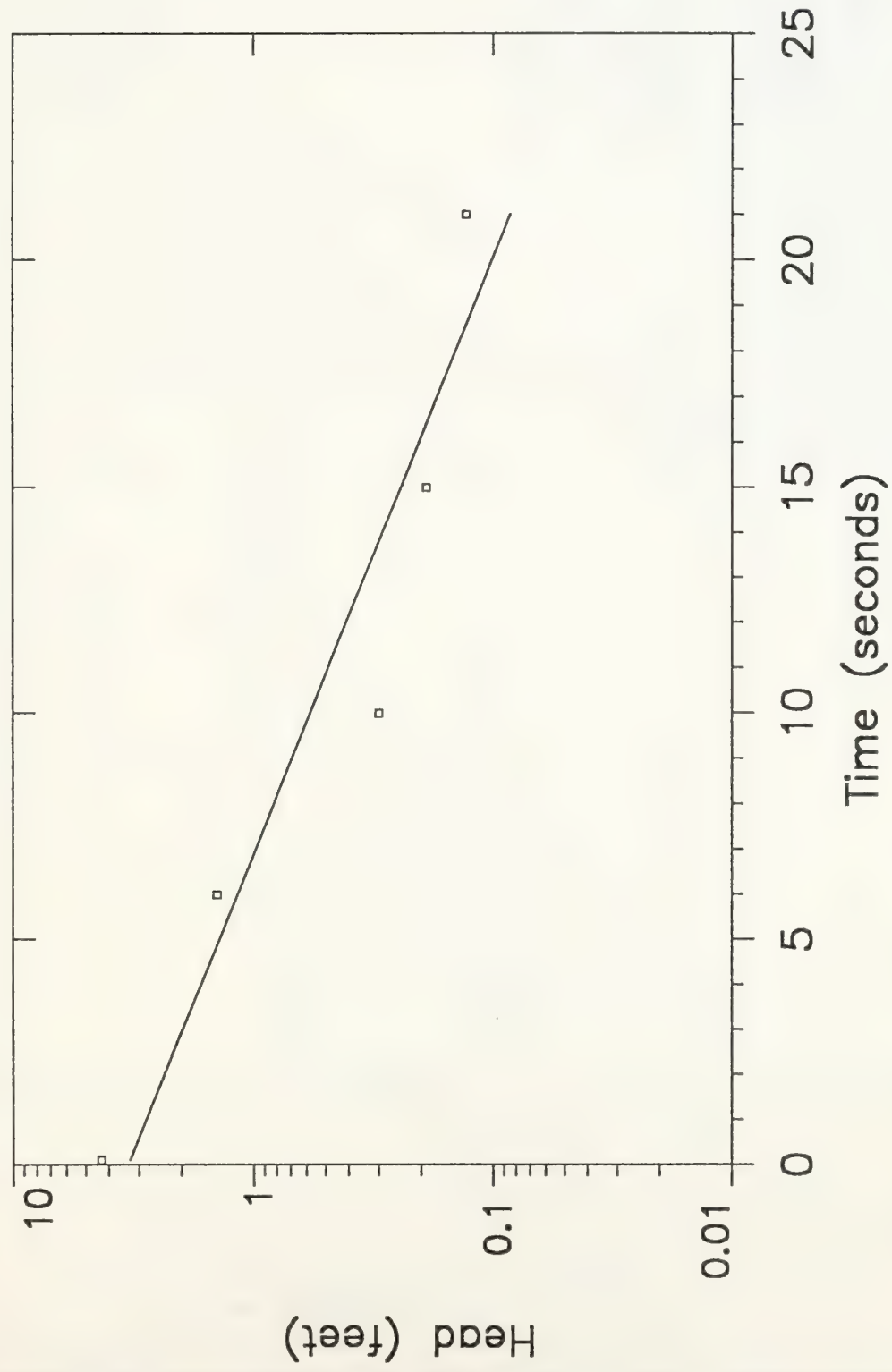
No.	TIME (secs)	Head, H (ft)		DIFFERENCE (percent)
		DATA	SYNTHETIC	
1	0.100	4.30	3.26	23.97
2	6.00	1.42	1.16	17.90
3	10.00	0.300	0.579	-93.14
4	15.00	0.190	0.241	-27.26
5	21.00	0.130	0.0847	34.82

CURRENT RESOLUTION MATRIIX NOT AVAILABLE

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Chen-Northern

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MODEL TYPE: BOUWER and RICE		Well Slug Test Data	
CONDUCTIVITY: 18.57 ft/day		Well: HMW-4	
TRANSMISSIVITY: 130.0 sq. ft/day		HUGHESVILLE, MT	
INITIAL HEAD: 4.300 ft		JUDITH BASIN COUNTY	
Data Set: HMW4IN		Date: NOV 26,90	
for: DSL/AMR		Chen-Northern	
by:			
WELL DATA: Units: ft			
AQUIFER: ALLUVIUM			
THICKNESS: 7.000			
SCREEN: top: 5.000 base: 12.00			
DIAMETER: casing: .1660 intake: .6400			
DEPTH: Water Table: 4.480 TD: 18.00			

DATA SET: DEFAULT

CLIENT: DSL\AMR	DATE: NOV 26,90
LOCATION: HUGHSVILLE, MT	WELL NO.: HMW-5
COUNTY: JUDITH BASIN COUNTY	WELL DEPTH: 122.00 ft
PROJECT: Well Slug Test Data	WATER TABLE: 0.000 ft
AQUIFER: BEDROCK	THICKNESS: 122.00 ft
E RADIUS: 0.240 ft	CASING RADIUS: 0.076 ft
REEN TOP: 85.000 ft	SCREEN BASE: 122.00 ft
IAL HEAD: 3.550 ft	TRANS. RATIO: 1.0000

MODEL PARAMETERS:

TRANSMISSIVITY: 4.34020square ft/day

CONDUCTIVITY: 0.03558 ft/day

L TYPE: UNCONFINED PARTIALLY PENETRATED AQUIFER (Bouwer & Rice)

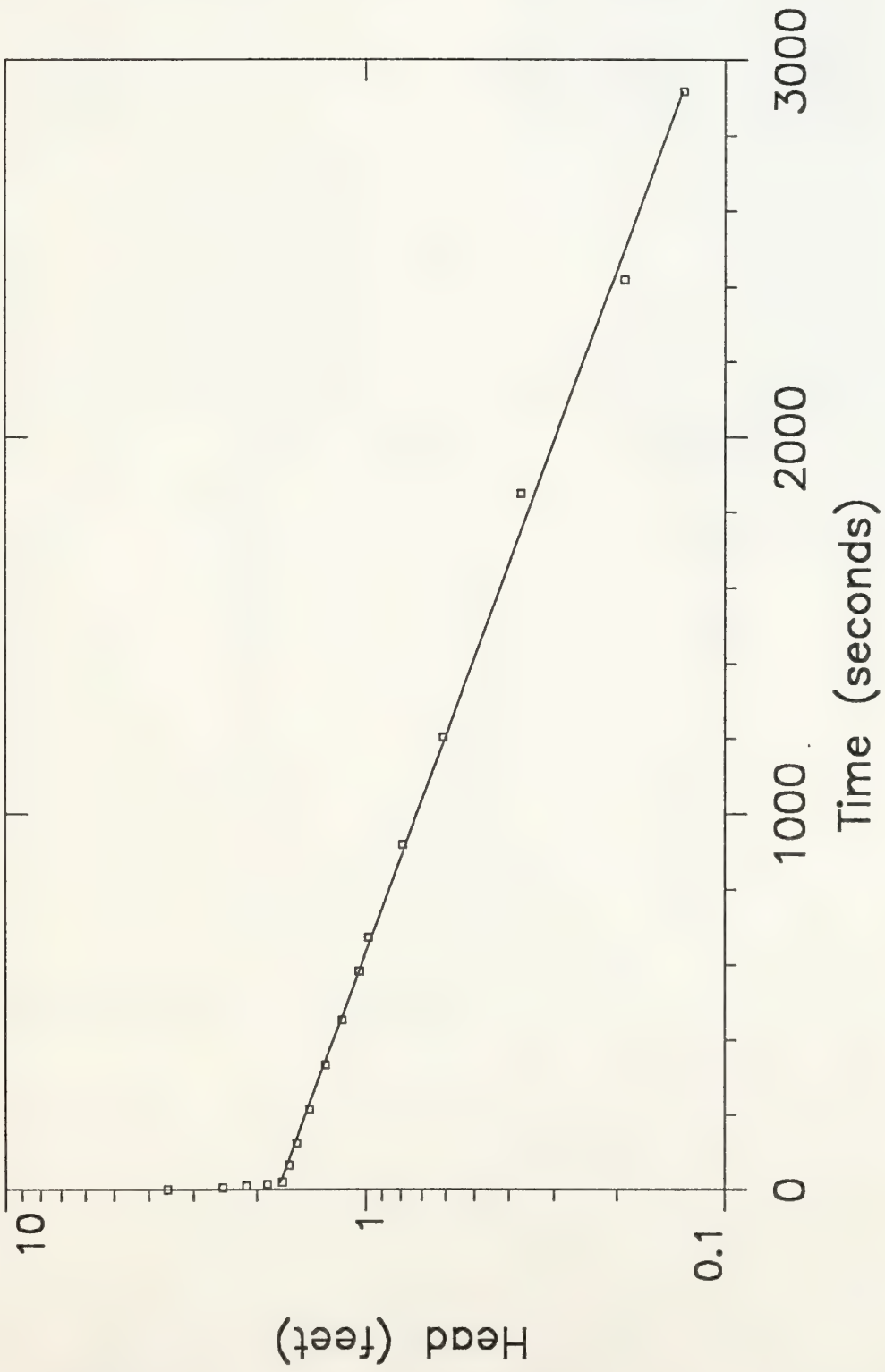
o.	TIME (secs)	Head, H (ft)		DIFFERENCE (percent)
		DATA	SYNTHETIC	
1	0.0100	3.55		
2	5.00	2.49		
3	10.00	2.14		
4	14.00	1.87		
5	20.00	1.70	1.71	-1.15
6	65.00	1.63	1.65	-1.36
7	125.0	1.55	1.56	-1.06
8	215.0	1.43	1.44	-1.13
9	335.0	1.29	1.30	-0.776
10	455.0	1.16	1.16	-0.741
11	585.0	1.04	1.04	-0.112
12	675.0	0.980	0.961	1.92
13	920.0	0.790	0.773	2.12
14	1205.0	0.610	0.600	1.58
15	1850.0	0.370	0.338	8.50
16	2420.0	0.190	0.204	-7.39
17	2915.0	0.130	0.131	-1.12

CURRENT RESOLUTION MATRIIX NOT AVAILABLE

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Chen-Northern

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MODEL TYPE: BOUWER and RICE		Well Slug Test Data	
CONDUCTIVITY: .03557 ft./day	for: DSL AMR	Well: HMW-5 HUGHSVILLE, MT JUDITH BASIN COUNTY	
TRANSMISSIVITY: 4.340 sq. ft./day	by: Chen-Northern		
INITIAL HEAD: 3.550 ft	WELL DATA: Units: ft		
	AQUIFER: BEDROCK		
	THICKNESS: 122.0	SCREEN: top: 85.00 base: 122.0 DIAMETER: casing: .1520 intake: .4800 DEPTH: Water Table: 0.000 TD: 122.0	
Data Set: DEFAULT	Date: NOV 26,90		

DATA SET: HMW-6IN

CLIENT: DSL/AMR	DATE: NOV 26,90
LOCATION: HUGHSEVILLE, MT	WELL NO.: HMW-6
COUNTY: JUDITH BASIN COUNTY	WELL DEPTH: 18.00 ft
PROJECT: Well Slug Test Data	WATER TABLE: 5.320 ft
AQUIFER: ALLUVIUM	THICKNESS: 10.00 ft
WELL RADIUS: 0.318 ft	CASING RADIUS: 0.083 ft
SCREEN TOP: 11.500 ft	SCREEN BASE: 18.00 ft
INITIAL HEAD: 4.300 ft	TRANS. RATIO: 1.0000

MODEL PARAMETERS:

TRANSMISSIVITY: 15.20481square ft/day

CONDUCTIVITY: 1.52048 ft/day

MODEL TYPE: UNCONFINED PARTIALLY PENETRATED AQUIFER (Bouwer & Rice)

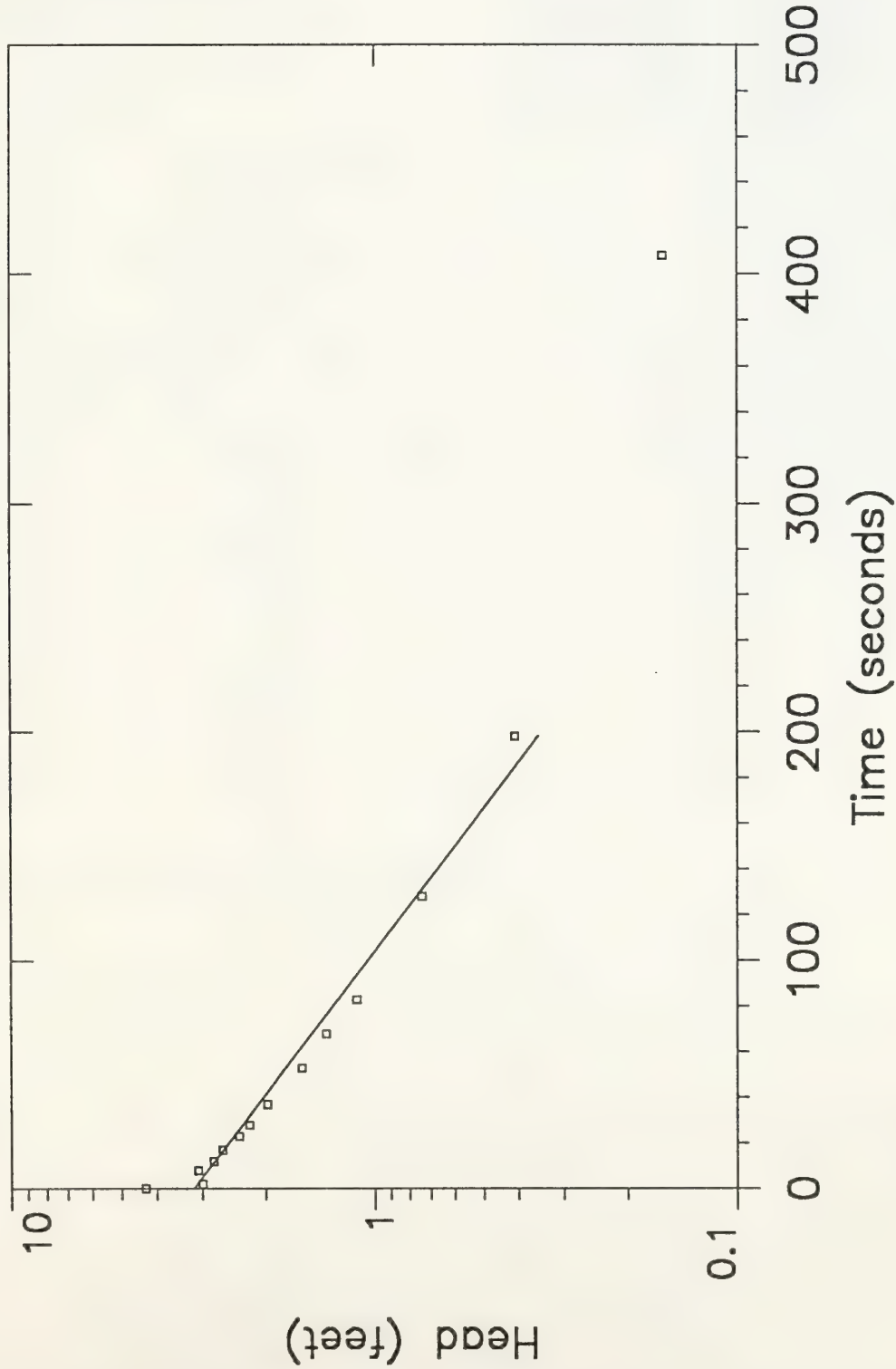
No.	TIME (secs)	Head, H (ft)		DIFFERENCE (percent)
		DATA	SYNTHETIC	
1	0.0100	4.30	3.17	26.22
2	2.00	3.00	3.10	-3.43
3	8.00	3.08	2.90	5.73
4	12.00	2.80	2.77	0.815
5	17.00	2.64	2.62	0.483
6	23.00	2.37	2.45	-3.71
7	28.00	2.22	2.32	-4.74
8	37.00	1.98	2.10	-6.27
9	53.00	1.59	1.76	-10.80
10	68.00	1.36	1.49	-9.68
11	83.00	1.12	1.26	-12.75
12	128.0	0.740	0.766	-3.56
13	198.0	0.410	0.352	14.04
14	408.0	0.160		

CURRENT RESOLUTION MATRIIX NOT AVAILABLE

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Chen-Northern

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MODEL TYPE: BOUWER and RICE		Well Slug Test Data	
CONDUCTIVITY: 1.520 ft/day		Well: HMW-6 HUGHSEVILLE, MT JUDITH BASIN COUNTY	
TRANSMISSIVITY: 15.20 sq. ft/day			
INITIAL HEAD: 4.300 ft			
Data Set: HMW-6IN	Date: NOV 28,90		
		for: DSL/AMR	
		by: Chen-Northern	
		WELL DATA: Units: ft	
		AQUIFER: ALLUVIUM	
		THICKNESS: 10.00	
		SCREEN: top: 11.50 base: 18.00	
		DIAMETER: casing: .1660 intake: .6360	
		DEPTH: Water Table: 5.320 TD: 18.00	

DATA SET: HMW-8IN

CLIENT: DSL/AMR	DATE: NOV 26, 90
LOCATION: HUGHSEVILLE, MT	WELL NO.: HMW-8
COUNTY: JUDITH BASIN COUNTY	WELL DEPTH: 25.00 ft
PROJECT: Well Slug Test Data	WATER TABLE: 8.420 ft
AQUIFER: BEDROCK	THICKNESS: 10.00 ft
WELL RADIUS: 0.240 ft	CASING RADIUS: 0.083 ft
SCREEN TOP: 17.000 ft	SCREEN BASE: 25.00 ft
INITIAL HEAD: 4.830 ft	TRANS. RATIO: 1.0000

MODEL PARAMETERS:

TRANSMISSIVITY: 78.16491 square ft/day

CONDUCTIVITY: 7.81649 ft/day

WELL TYPE: UNCONFINED PARTIALLY PENETRATED AQUIFER (Bouwer & Rice)

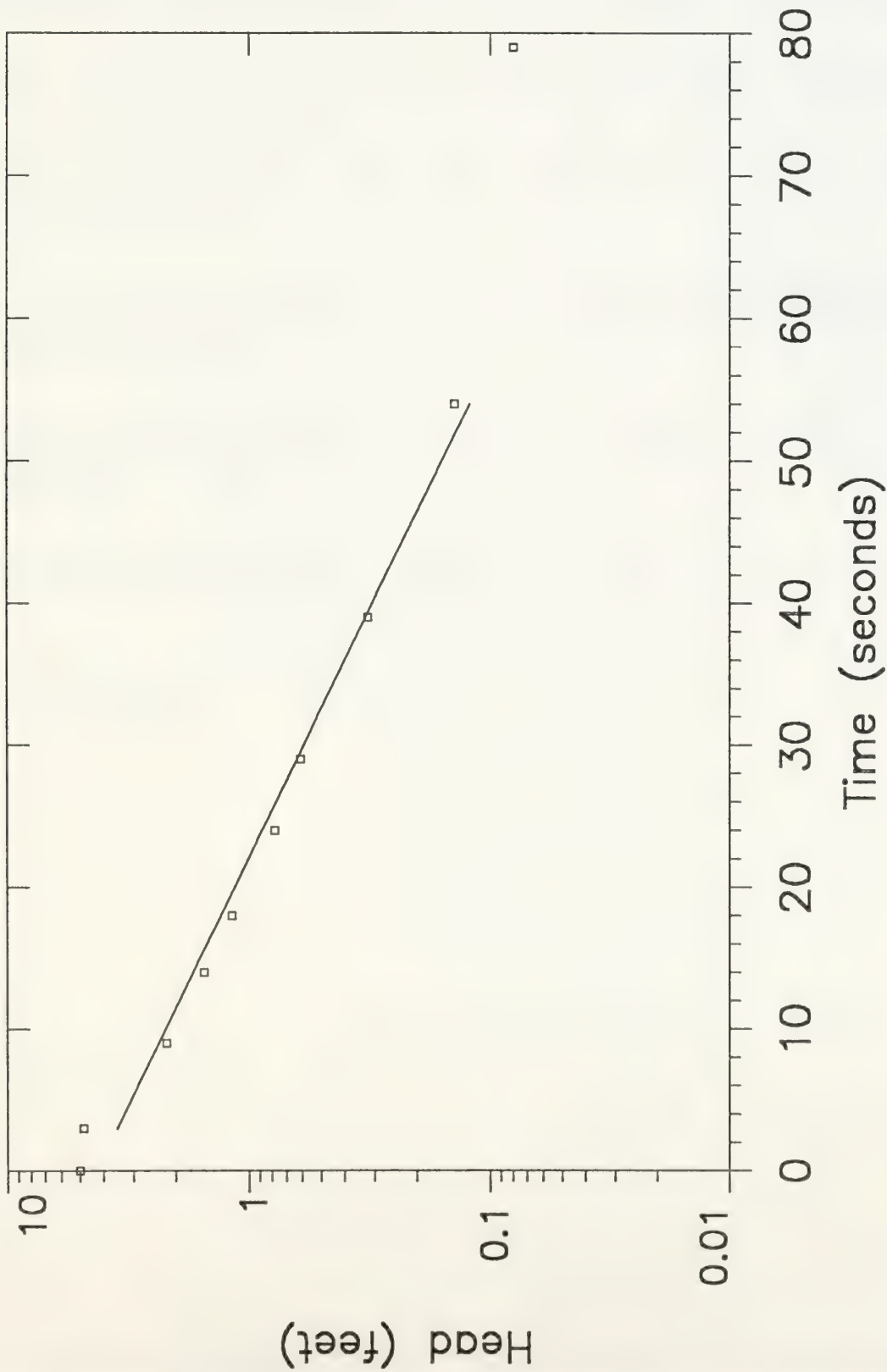
No.	TIME (secs)	Head, H (ft)		DIFFERENCE (percent)
		DATA	SYNTHETIC	
1	0.0100	5.00		
2	3.00	4.83	3.50	27.38
3	9.00	2.18	2.36	-8.29
4	14.00	1.53	1.69	-10.94
5	18.00	1.17	1.30	-11.43
6	24.00	0.780	0.877	-12.52
7	29.00	0.610	0.631	-3.45
8	39.00	0.320	0.326	-1.96
9	54.00	0.140	0.121	13.35
10	79.00	0.0800		

CURRENT RESOLUTION MATRIX NOT AVAILABLE

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Chen-Northern

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MODEL TYPE: BOUWER and RICE

CONDUCTIVITY: 7.816 ft/day

TRANSMISSIVITY: 78.16 sq. ft/day

INITIAL HEAD: 4.830 ft

Data Set: HMW-8IN

Date: NOV 26,90

for: DSL/AMR

by: Chen-Northern

WELL DATA: Units: ft

AQUIFER: BEDROCK

THICKNESS: 10.00

SCREEN: top: 17.00 base: 25.00

DIAMETER: casing: .1660 intake: .4800

DEPTH: Water Table: 8.420 TD: 25.00

Well Slug Test Data

Well: HMW-8
HUGHSEVILLE, MT
JUDITH BASIN COUNTY

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December 24, 1975.
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Counties, Montana. Map GQ-898.

APPENDIX C
SOILS/MINE WASTE

APPENDIX C-1

XRF DATA BASE, REGRESSION ANALYSES, AND PREDICTIVE CURVES FOR XRF DATA

GALENA CREEK PRELIMINARY ASSESSMENT
XRF CALIBRATION STANDARD MEASUREMENTS

Page 1 of 2

SAMPLE	DATE	AS	CU	FE	MN	NI	PB	ZN
		XRF INDEX	XRF INDEX	XRF INDEX	XRF INDEX	XRF INDEX	XRF INDEX	XRF INDEX
S1150001	121990	1.00	0.37	2.00	1.82	0.49	1.88	0.33
S1151236	121990	0.96	0.38	2.49	2.28	0.51	1.77	0.34
S1770001	121990	1.45	0.43	2.24	2.04	0.53	2.74	0.43
S1171836	121990	1.93	0.52	2.55	2.38	0.60	3.72	0.53
S1173648	121990	1.82	0.53	2.73	2.61	0.62	3.40	0.53
S1211836	121990	0.76	0.37	2.63	2.43	0.51	1.39	0.32
S1221836	121990	1.02	0.37	2.81	2.63	0.54	1.87	0.34
S1121561	121990	1.52	0.54	3.79	3.61	0.72	2.76	0.51
S1240001	121990	2.14	0.58	2.18	2.08	0.60	4.17	0.65
S1240112	121990	0.94	0.38	1.78	1.65	0.45	1.81	0.36
S1241240	121990	0.51	0.27	1.40	1.33	0.34	0.94	0.24
S1300001	121990	2.30	0.61	2.60	2.50	0.67	4.78	0.60
S1301230	121990	1.50	0.50	3.09	2.98	0.63	2.74	0.45
S1330001	121990	2.43	0.99	5.23	5.10	1.09	4.45	1.03
S1330324	121990	2.66	0.59	2.14	2.09	0.61	5.00	0.66
S1341022	121990	0.67	0.35	2.87	2.81	0.50	1.17	0.28
S1350001	121990	1.64	0.43	1.48	1.47	0.43	3.23	0.44
S1351536	121990	1.47	0.48	1.44	1.41	0.46	2.86	0.51
S1361536	121990	1.90	0.54	1.59	1.40	0.50	3.76	0.60
S1076672	121990	0.75	0.34	1.74	1.50	0.43	1.36	0.30
S1094866	121990	0.79	0.47	3.77	3.05	0.73	1.45	0.40
S1096613	121990	1.37	1.07	5.44	4.59	1.18	2.28	1.13
S1120001	121990	1.76	0.52	2.83	2.48	0.64	3.34	0.52
S1122162	121990	0.58	0.32	2.09	1.79	0.43	1.04	0.27
S1000001	121990	1.88	0.65	2.10	1.88	0.62	3.55	0.74
S1000118	121990	1.44	0.49	4.20	3.68	0.77	2.50	0.42
S1001836	121990	0.41	0.36	2.30	1.98	0.48	0.76	0.30
S1020001	121990	1.10	0.38	1.71	1.50	0.43	2.06	0.39
S1020848	121990	0.54	0.50	2.98	2.65	0.63	0.99	0.45
S1024860	121990	0.43	0.36	1.12	0.98	0.37	0.81	0.36
S1050001	121990	1.80	0.56	2.18	1.97	0.58	3.32	0.58
S1050106	121990	2.37	0.60	2.61	2.30	0.68	4.37	0.64
S1050612	121990	1.00	0.62	6.82	5.94	1.07	1.62	0.47
S1070001	121990	0.97	0.40	2.30	2.03	0.53	1.81	0.37
S1070166	121990	0.94	0.48	3.48	3.01	0.67	1.65	0.44
S1370001	121990	0.87	0.66	7.44	7.00	1.16	1.63	0.52
S1370124	121990	0.71	0.58	7.70	6.81	1.15	1.26	0.40
S1372448	121990	0.94	0.63	9.43	8.35	1.38	1.71	0.40
HMW51011	121990	1.25	0.50	2.38	2.12	0.57	2.38	0.53

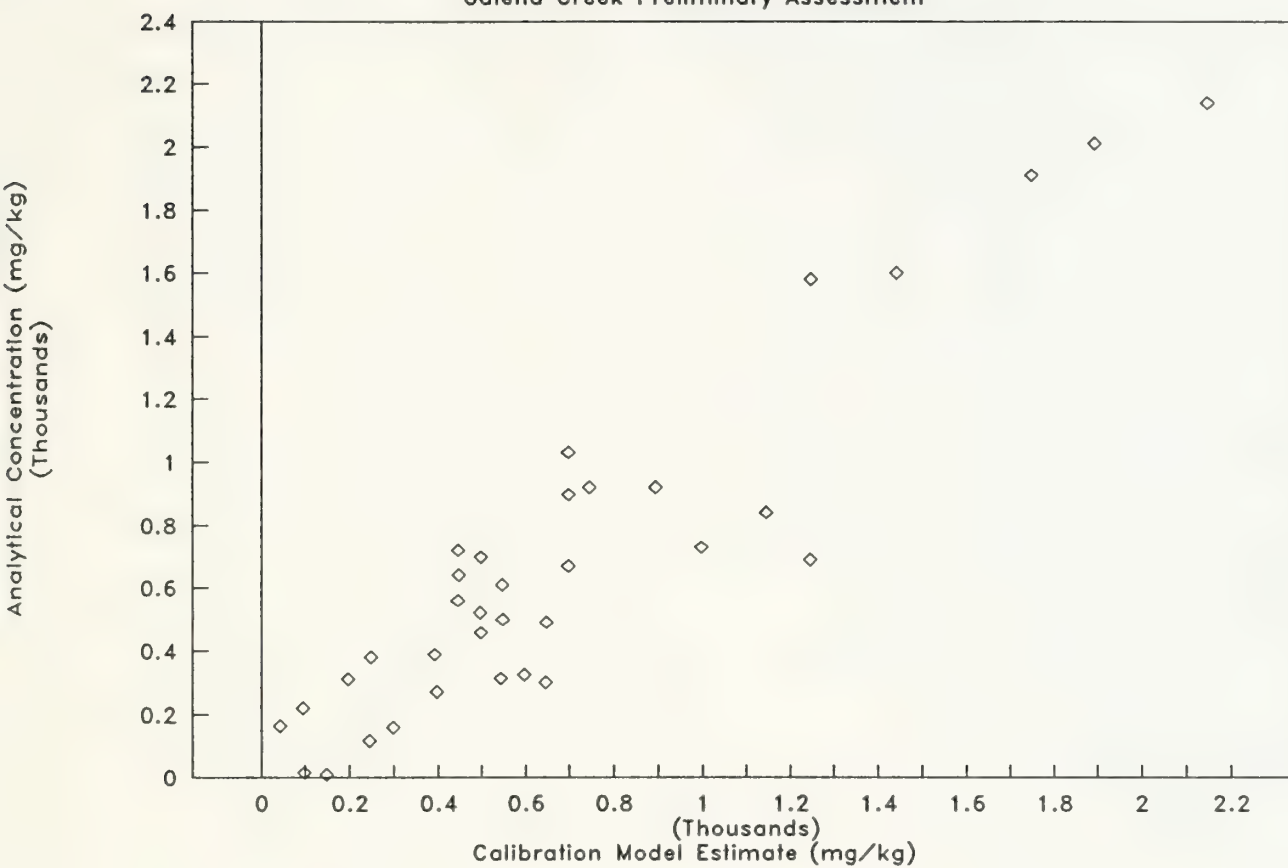
GALENA CREEK PRELIMINARY ASSESSMENT
XRF CALIBRATION STANDARD MEASUREMENTS

Page 2 of 2

SAMPLE	DATE	AS LAB VALUE	CU LAB VALUE	FE LAB VALUE	MN LAB VALUE	NI LAB VALUE	PB LAB VALUE	ZN LAB VALUE
S1150001		720	46	30700	38	5	11700	314
S1151236		324	76	27500	44	6	4050	130
S1770001		299	88	29100	16	3	10200	453
S1171836		312	93	29300	34	7	23600	340
S1173648		478	111	39600	31	10	24600	975
S1211836		457	32	41100	26	4	4210	313
S1221836		1030	37	59900	29	8	9360	184
S1121561		1580	314	81000	3290	13	10000	860
S1240001		388	55	25400	36	5	40700	2150
S1240112		311	31	16600	93	6	3270	262
S1241240		380	11	15700	80	8	291	78
S1300001		510	332	33300	29	8	34000	792
S1301230		840	172	40100	38	10	9170	626
S1330001		2010	568	65400	63	17	18600	4830
S1330324		1600	206	25200	40	10	18000	558
S1341022		897	36	37000	1410	16	1030	249
S1350001		220	40	17400	13	13	22000	388
S1351536		116	129	15400	31	8	12200	1000
S1361536		164	160	18500	29	10	22800	2000
S1076672		500	79	27300	10	12	2810	562
S1094866		698	157	91500	67	22	2070	905
S1096613		2140	688	141000	115	38	4460	76
S1120001		920	312	50400	1630	14	10600	731
S1122162		640	190	33900	1440	21	680	321
S1000001		920	220	23200	28	13	13500	3010
S1000118		2040	130	60000	180	28	6340	630
S1001836		9	187	23500	123	37	91	478
S1020001		610	138	22900	38	10	6130	553
S1020848		160	268	57300	1340	24	451	1220
S1024860		16	369	12300	94	22	408	858
S1050001		690	349	26100	26	11	12200	1450
S1050106		1050	410	34400	76	12	18500	1090
S1050612		1910	980	73600	10900	27	1540	1070
S1070001		520	254	43400	18	16	4000	588
S1070166		730	179	78400	6	22	2310	950
S1370001		270	2140	134000	15600	42	8690	1580
S1370124		490	483	121000	5108	30	1340	613
S1372448		670	845	148000	2040	22	4100	503
HMW51011		560	106	37800	216	9	11500	2800

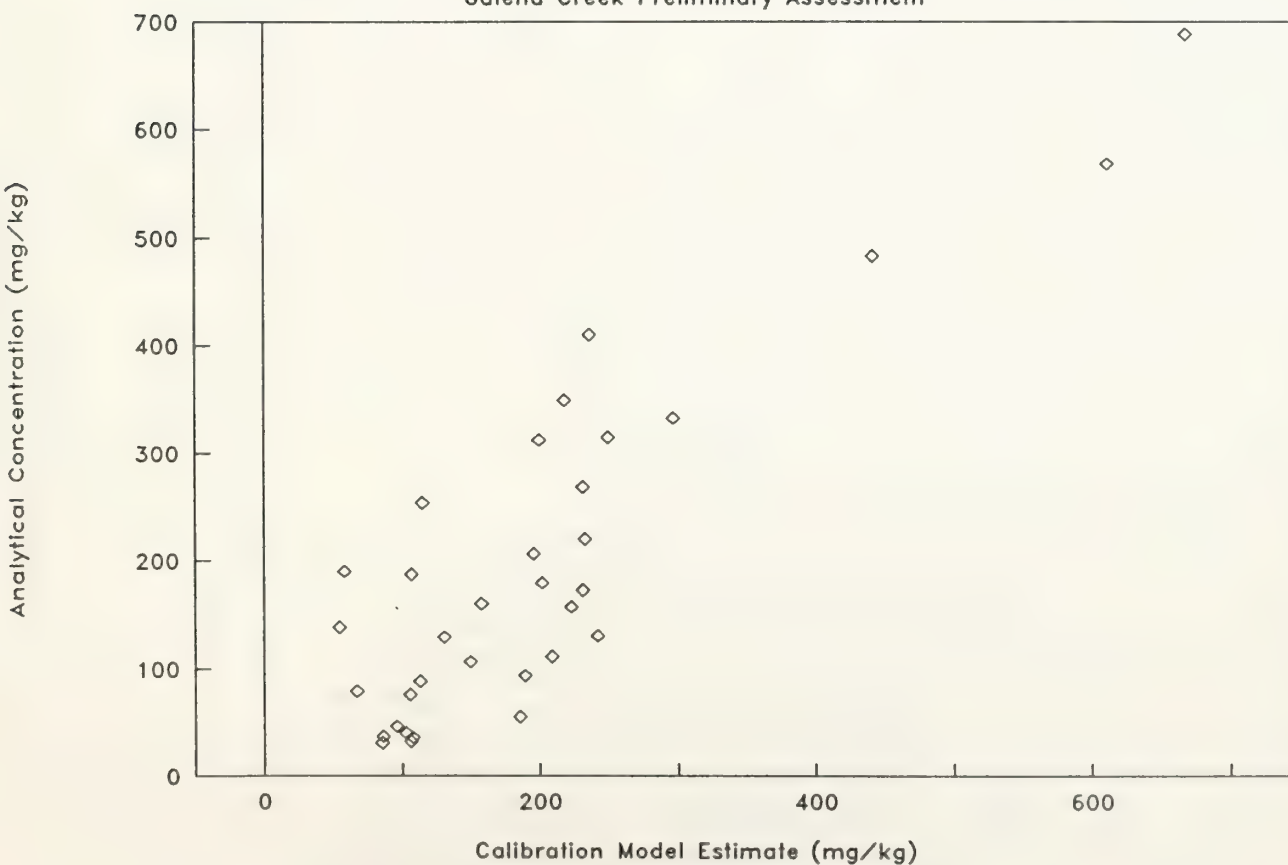
XRF CALIBRATION MODEL – ARSENIC

Galena Creek Preliminary Assessment



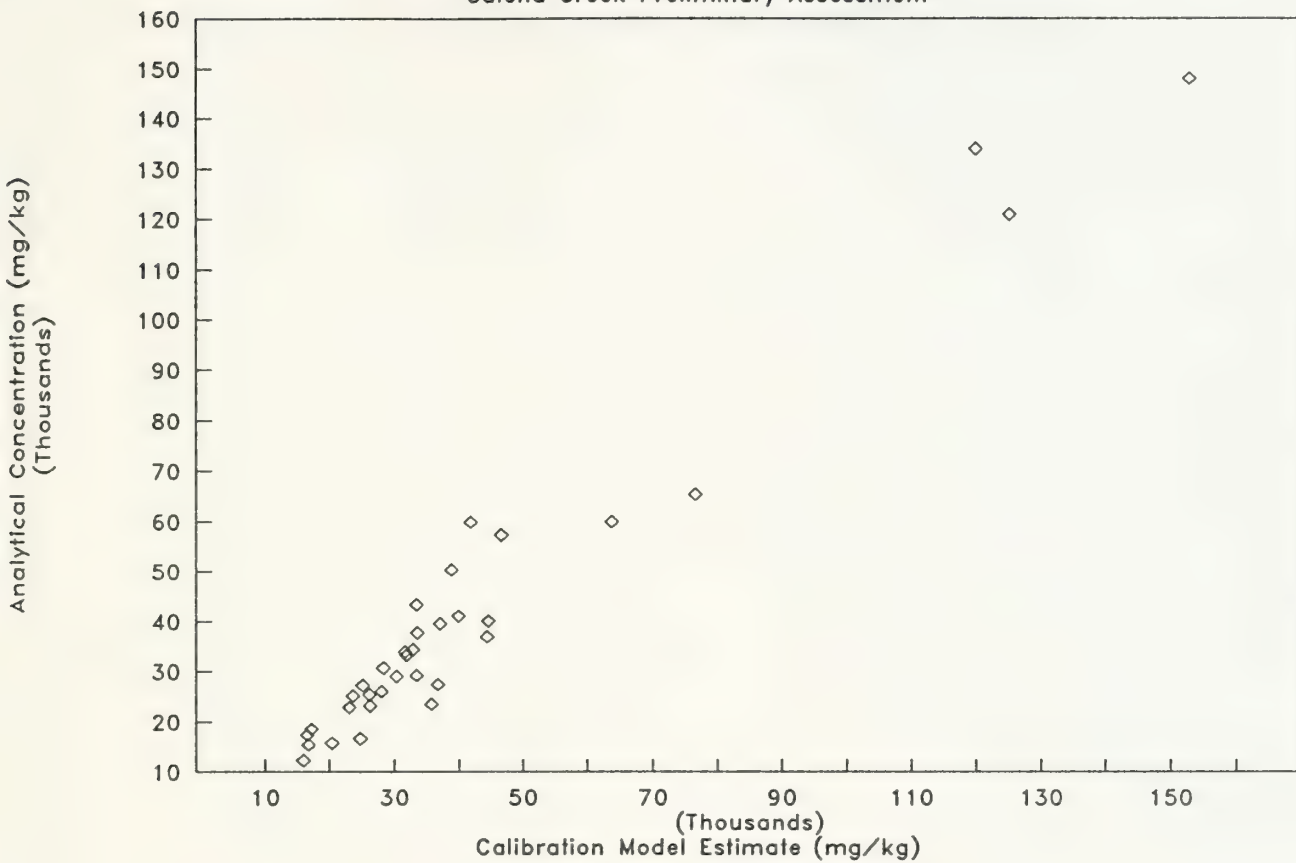
XRF CALIBRATION MODEL – COPPER

Galena Creek Preliminary Assessment



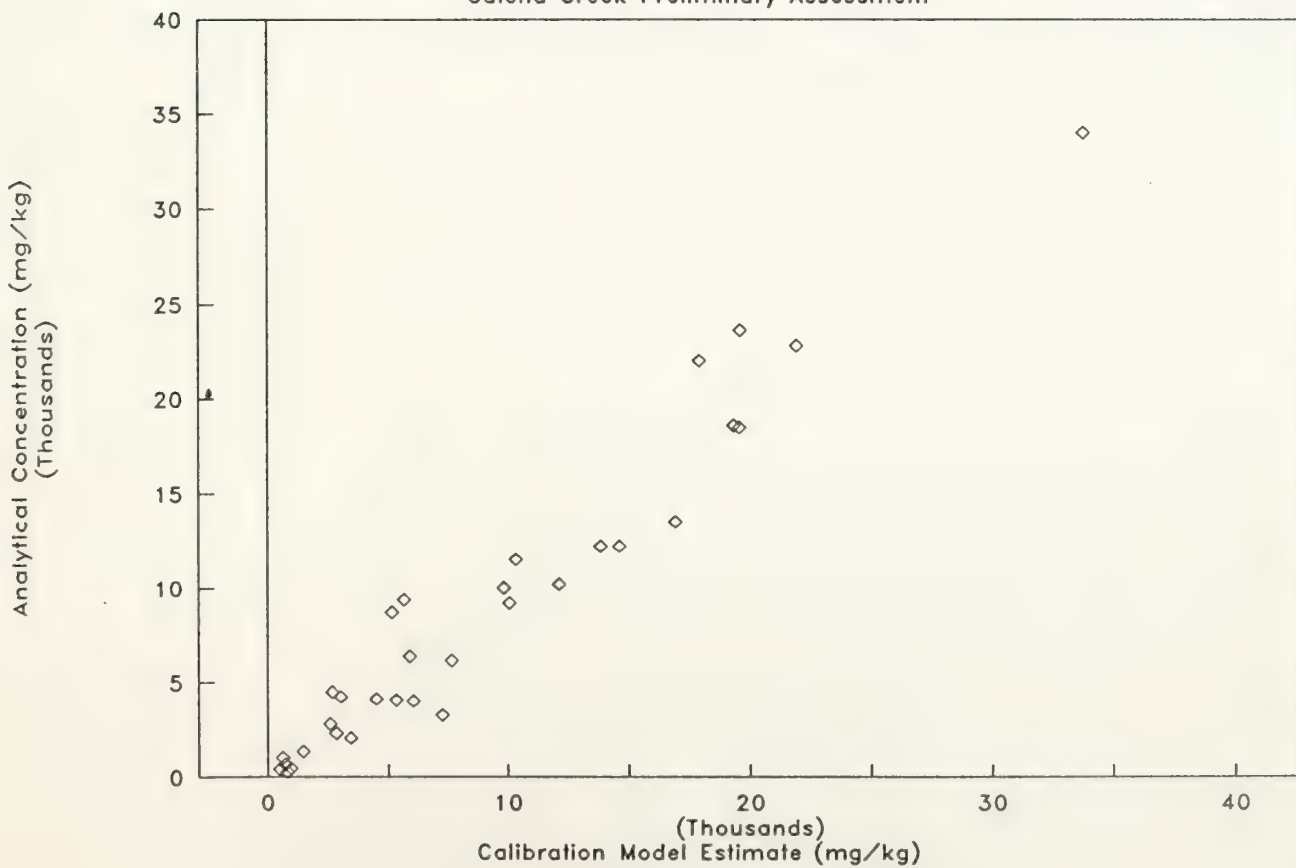
XRF CALIBRATION MODEL – IRON

Galena Creek Preliminary Assessment



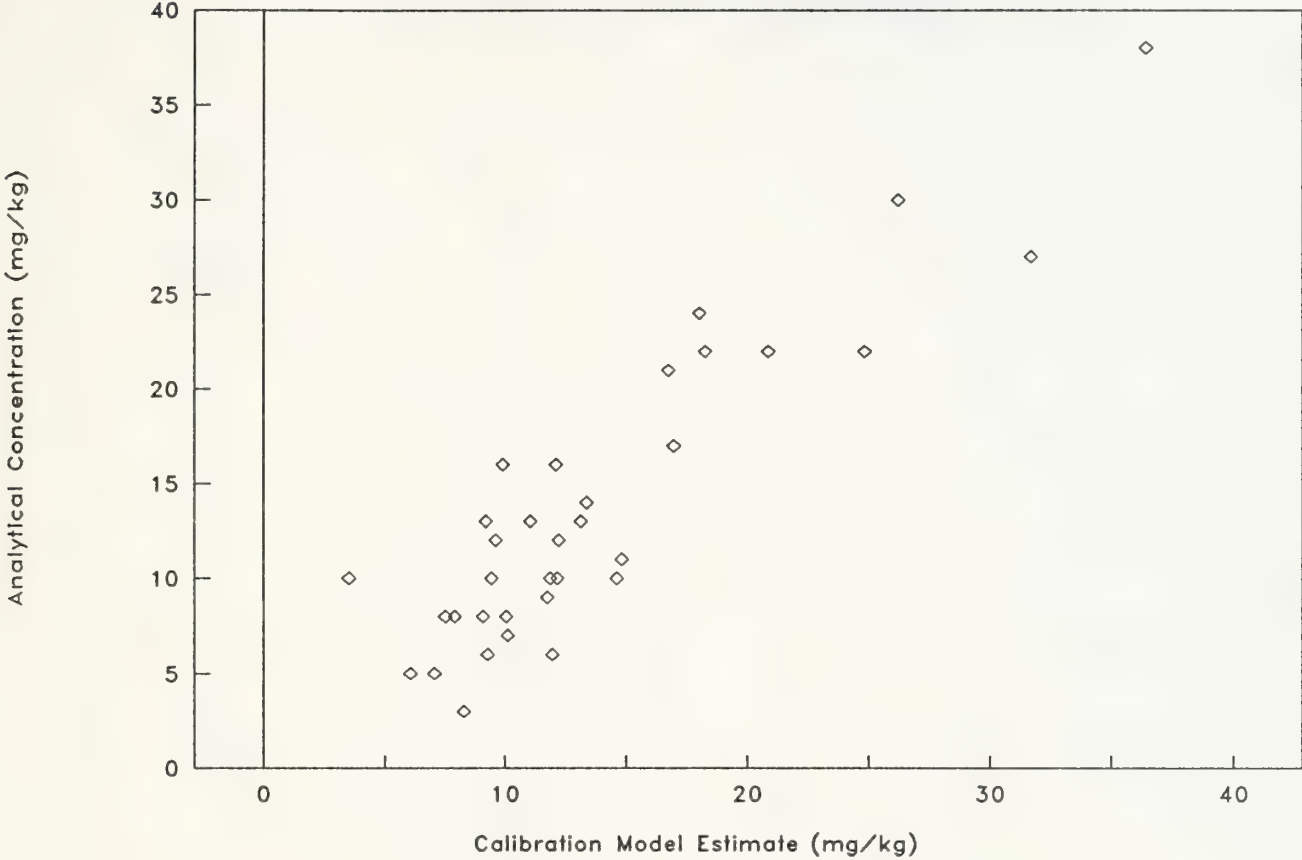
XRF CALIBRATION MODEL – LEAD

Galena Creek Preliminary Assessment



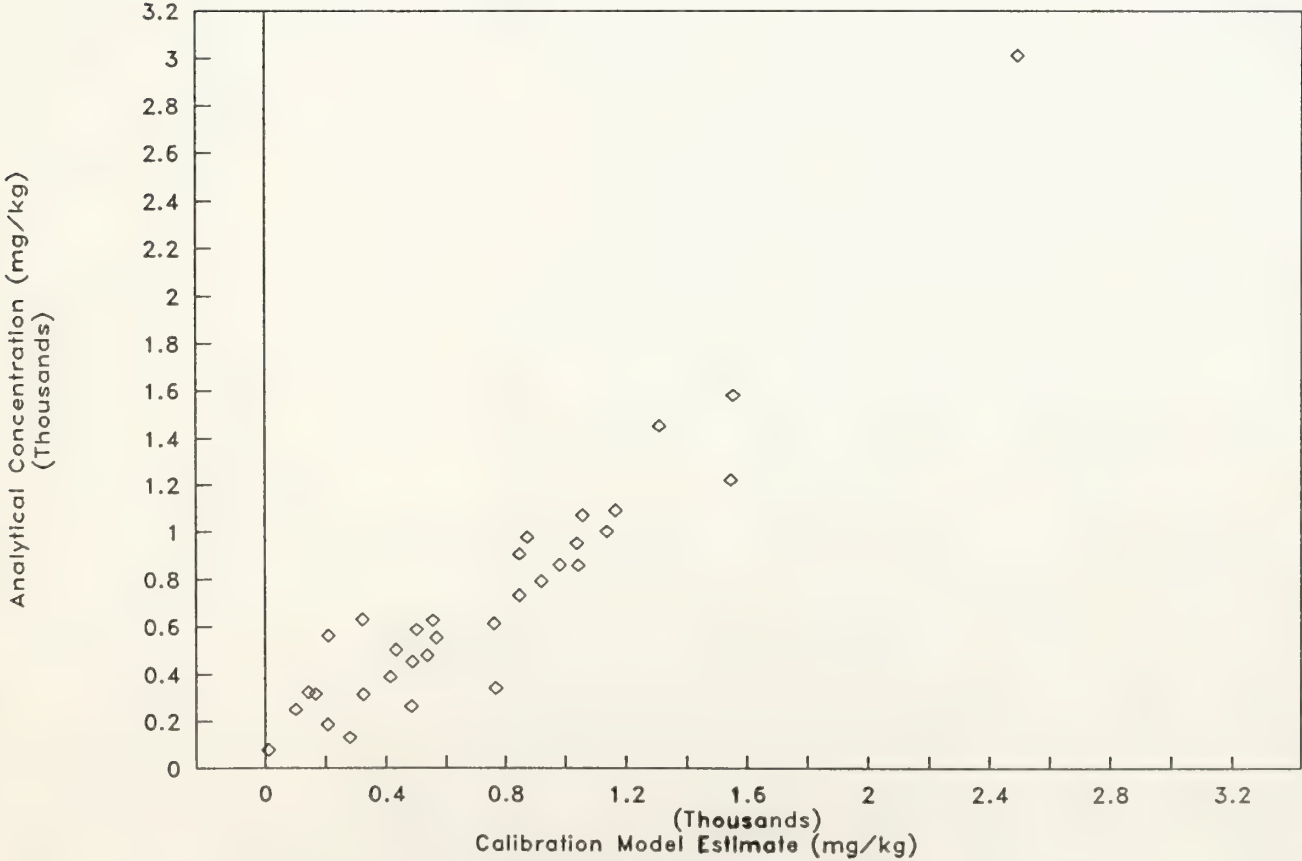
XRF CALIBRATION MODEL – NICKEL

Galena Creek Preliminary Assessment



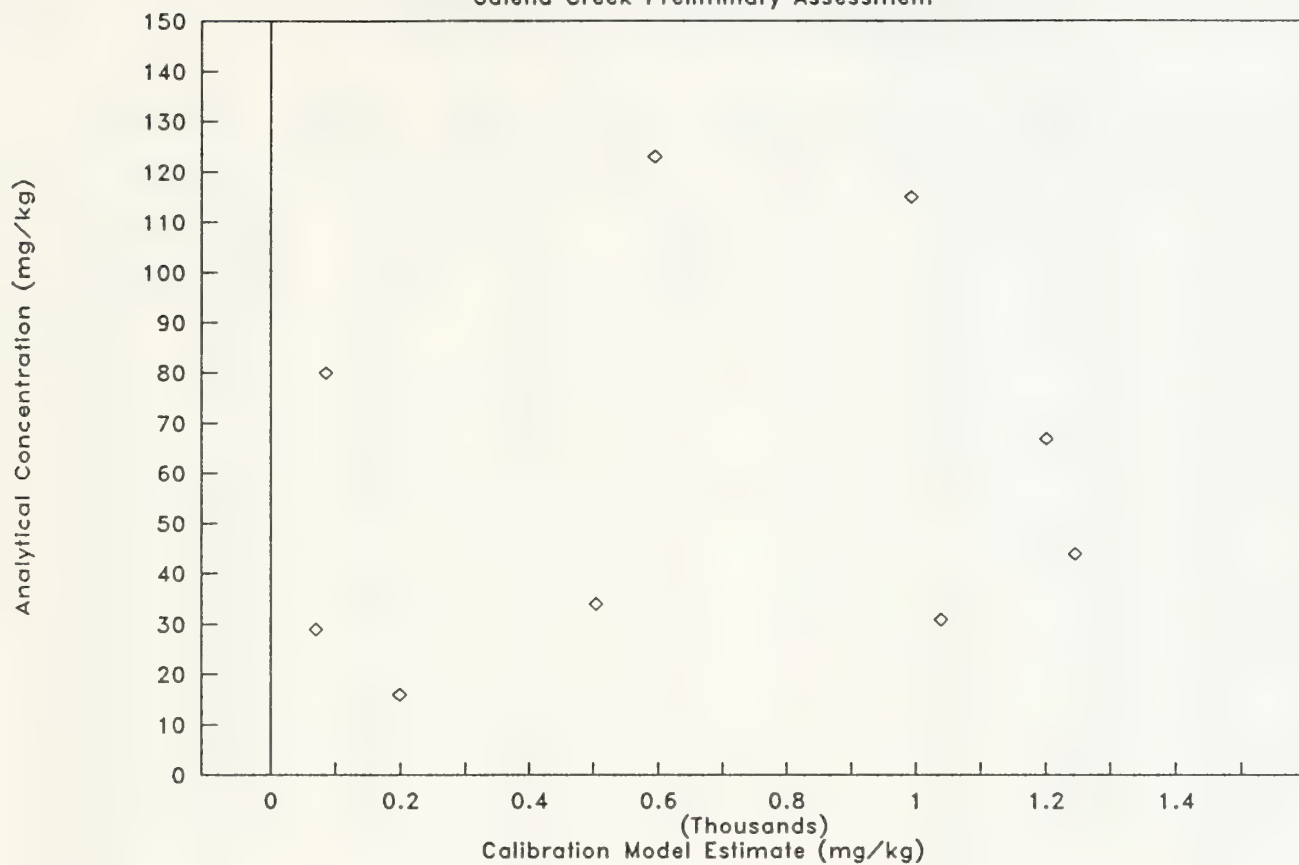
XRF CALIBRATION MODEL – ZINC

Galena Creek Preliminary Assessment



XRF CALIBRATION MODEL — MANGANESE

Galena Creek Preliminary Assessment



GALENA CREEK PRELIMINARY ASSESSMENT
SOIL/MINE WASTE XRF INDEX AND PREDICTED METAL CONCENTRATIONS
Page 1 of 3

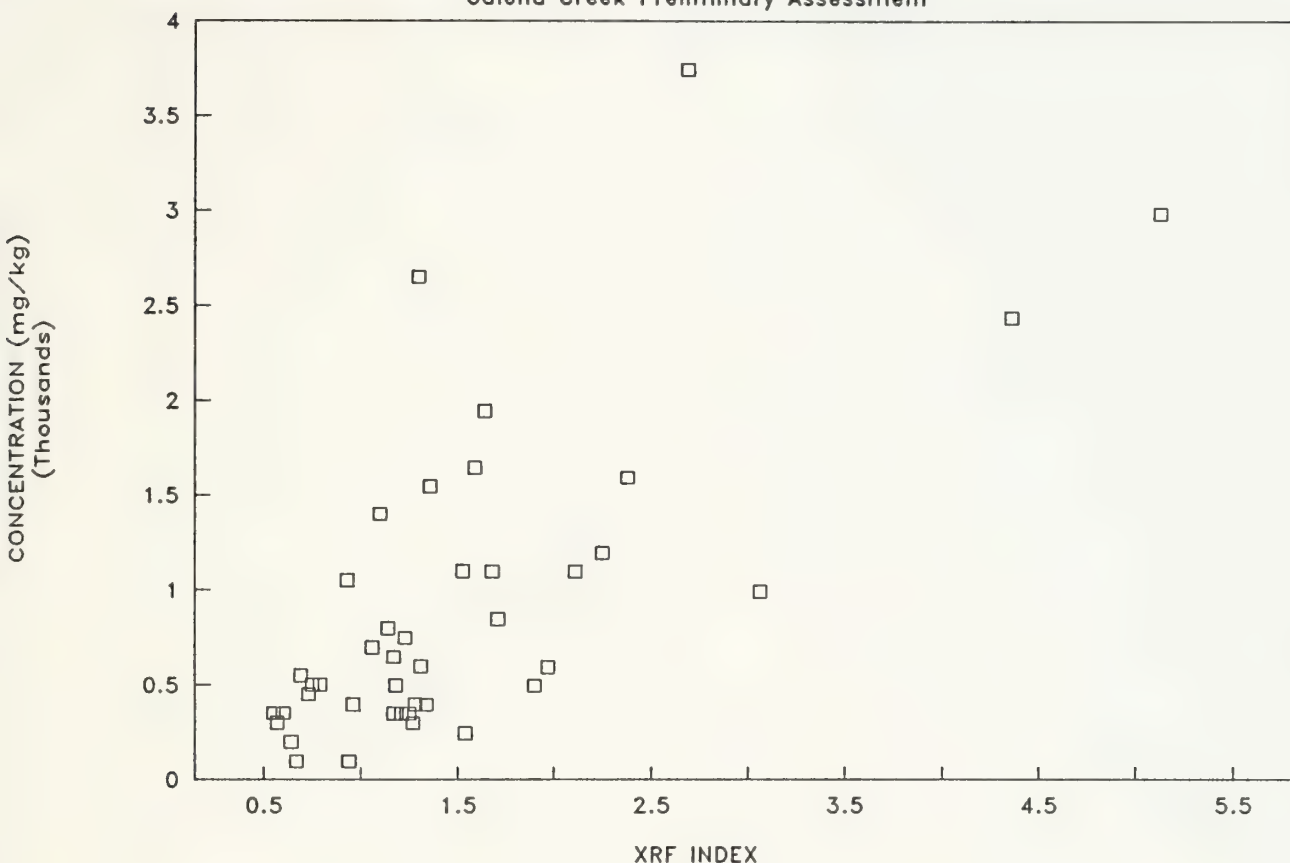
SAMPLE	DATE	AS XRF INDEX	CU XRF INDEX	FE XRF INDEX	MN XRF INDEX	NI XRF INDEX	PB XRF INDEX	ZN XRF INDEX
HMW52224	121990	0.96	0.41	2.13	1.66	0.54	1.81	0.38
S1010001	121990	4.36	1.93	5.76	5.09	1.64	8.20	2.33
S1010120	121990	1.21	0.44	1.84	1.63	0.50	2.32	0.44
S1030001	121990	1.06	0.40	2.42	2.06	0.55	1.95	0.38
S1030138	121990	2.25	0.84	2.73	2.41	0.77	4.23	0.98
S1033847	121990	2.69	2.61	4.78	4.28	1.69	4.60	3.34
S1040001	121990	1.68	0.66	2.83	2.42	0.71	3.11	0.70
S1040115	122090	2.38	1.07	2.79	2.51	0.87	4.41	1.26
S1041548	122090	1.10	0.43	3.05	2.79	0.63	1.89	0.38
S1060004	122090	3.06	0.76	2.12	2.01	0.72	5.89	0.89
S1060412	122090	0.64	0.31	1.49	1.36	0.37	1.21	0.28
S1080001	122090	0.57	0.30	1.54	1.41	0.38	1.05	0.27
S1083648	122090	0.73	0.49	2.76	2.48	0.59	1.34	0.44
S1087892	122090	1.64	0.68	3.37	3.15	0.78	2.86	0.63
S1110001	122090	1.59	0.61	5.46	5.11	0.92	2.82	0.53
S1116084	122090	0.93	0.53	4.74	4.45	0.82	1.62	0.42
S1111081	122090	1.30	0.90	5.46	5.16	1.06	2.04	0.89
S1131236	122090	1.90	0.50	2.32	2.11	0.56	3.67	0.55
S1141230	122090	0.67	0.32	1.80	1.61	0.41	1.29	0.29
S1181236	122090	1.17	0.43	2.75	2.59	0.55	2.18	0.40
S1161230	122090	1.25	0.46	2.01	2.01	0.51	2.40	0.46
S1192846	122090	1.54	0.44	1.81	1.73	0.48	3.00	0.43
S1201836	122090	1.27	0.50	2.06	2.02	0.53	2.45	0.51
S1231830	122090	0.60	0.37	3.78	3.66	0.60	1.10	0.28
S1250114	122090	1.23	0.49	1.92	1.76	0.47	2.28	0.51
S1251436	122090	2.11	0.55	2.19	2.15	0.59	3.97	0.61
S1260001	122090	1.18	0.44	1.89	1.95	0.47	2.23	0.43
S1261236	122090	1.17	0.48	2.41	2.47	0.52	2.24	0.47
S1271236	122090	1.34	0.42	1.47	1.49	0.41	2.57	0.46
S1281236	122090	5.13	1.02	4.13	4.43	1.05	9.63	1.11
S1290001	122090	1.28	0.45	1.88	1.87	0.50	2.45	0.47
S1291230	122090	1.97	0.50	2.13	2.24	0.55	3.79	0.54
S1311236	122090	1.17	0.40	1.58	1.61	0.43	2.18	0.39
S1320001	122090	1.14	0.83	3.74	3.97	0.76	2.09	0.82
S1321230	122090	0.94	0.45	1.73	1.77	0.44	1.83	0.45
S1340001	122090	1.71	0.71	3.34	3.53	0.71	3.22	0.75
S1340108	122090	1.53	0.47	3.04	3.14	0.57	2.81	0.48
S1380001	122090	0.55	0.44	2.77	2.85	0.58	1.00	0.34
S1380112	122090	0.43	0.29	1.35	1.40	0.33	0.81	0.26
S1383648	122090	0.41	0.27	0.77	0.81	0.28	0.78	0.25
S1090001	121990	0.75	0.40	3.39	2.85	0.67	1.37	0.34
S1090148	121990	0.69	0.33	1.95	1.65	0.44	1.24	0.30
S1100001	121990	1.31	0.39	2.07	1.74	0.49	2.47	0.37
S1103654	121990	0.79	0.42	3.62	3.07	0.66	1.45	0.35
S1108490	121990	1.36	0.79	5.20	4.98	0.98	2.38	0.82

GALENA CREEK PRELIMINARY ASSESSMENT
SOIL/MINE WASTE XRF INDEX AND PREDICTED METAL CONCENTRATIONS
Page 2 of 3

SAMPLE	DATE	AS PREDICTED	CU PREDICTED	FE PREDICTED	MN PREDICTED	NI PREDICTED	PB PREDICTED	ZN PREDICTED
HMW52224	121990	396	125	30587	-1199	14	6441	588
S1010001	121990	2436	1147	77063	-2833	39	43971	12254
S1010120	121990	345	123	24590	-821	10	10308	827
S1030001	121990	696	105	35129	27	10	6222	481
S1030138	121990	1192	364	35217	-1431	19	20558	3970
S1033847	121990	3744	1464	68712	-6157	75	12813	22032
S1040001	121990	1094	293	39398	-678	18	12922	2340
S1040115	122090	1592	534	35818	-2292	27	20219	6037
S1041548	122090	1397	164	45811	1524	7	2936	408
S1060004	122090	989	298	21288	-2177	3	33296	2437
S1060412	122090	197	29	21214	-173	11	2947	184
S1080001	122090	297	19	22409	-124	8	1390	172
S1083648	122090	447	222	42187	960	19	2861	1284
S1087892	122090	1946	404	48998	939	16	7659	1793
S1110001	122090	1646	368	84081	5856	15	8595	988
S1116084	122090	1047	322	74711	4833	13	2425	826
S1111081	122090	2648	575	85826	4348	21	-1086	4110
S1131236	122090	492	129	29605	75	9	19391	973
S1141230	122090	97	38	26225	189	11	3930	218
S1181236	122090	646	144	40139	1810	12	8078	528
S1161230	122090	345	142	27257	337	6	10882	941
S1192846	122090	243	133	22566	-245	10	15599	415
S1201836	122090	295	170	27982	132	9	11445	1313
S1231830	122090	347	147	59802	4810	11	1546	133
S1250114	122090	746	150	26019	-25	19	8388	1378
S1251436	122090	1093	167	26757	-150	2	19098	1226
S1260001	122090	495	133	25629	615	8	9049	789
S1261236	122090	345	171	34313	1765	11	9733	1100
S1271236	122090	395	63	17836	-214	7	11899	889
S1281236	122090	2984	588	46572	2012	-5	51998	1937
S1290001	122090	395	112	24969	-14	3	11037	995
S1291230	122090	592	140	26156	632	-1	19845	825
S1311236	122090	646	95	20550	-50	7	8078	496
S1320001	122090	796	508	56916	3937	26	6820	3835
S1321230	122090	96	132	23845	368	12	7808	1208
S1340001	122090	844	342	47690	3056	11	14732	2709
S1340108	122090	1095	141	43585	3420	5	10767	790
S1380001	122090	348	225	43115	2325	6	827	673
S1380112	122090	98	9	19765	441	8	483	256
S1383648	122090	48	-20	10121	-945	6	471	217
S1090001	121990	497	146	52668	1247	10	2873	431
S1090148	121990	547	48	28849	-35	13	1735	265
S1100001	121990	595	95	28105	-331	13	10365	168
S1103654	121990	497	175	56340	2107	18	3447	474
S1108490	121990	1546	429	80712	4700	11	5843	3521
AVERAGE		873	251	39269	724	13	10681	1987

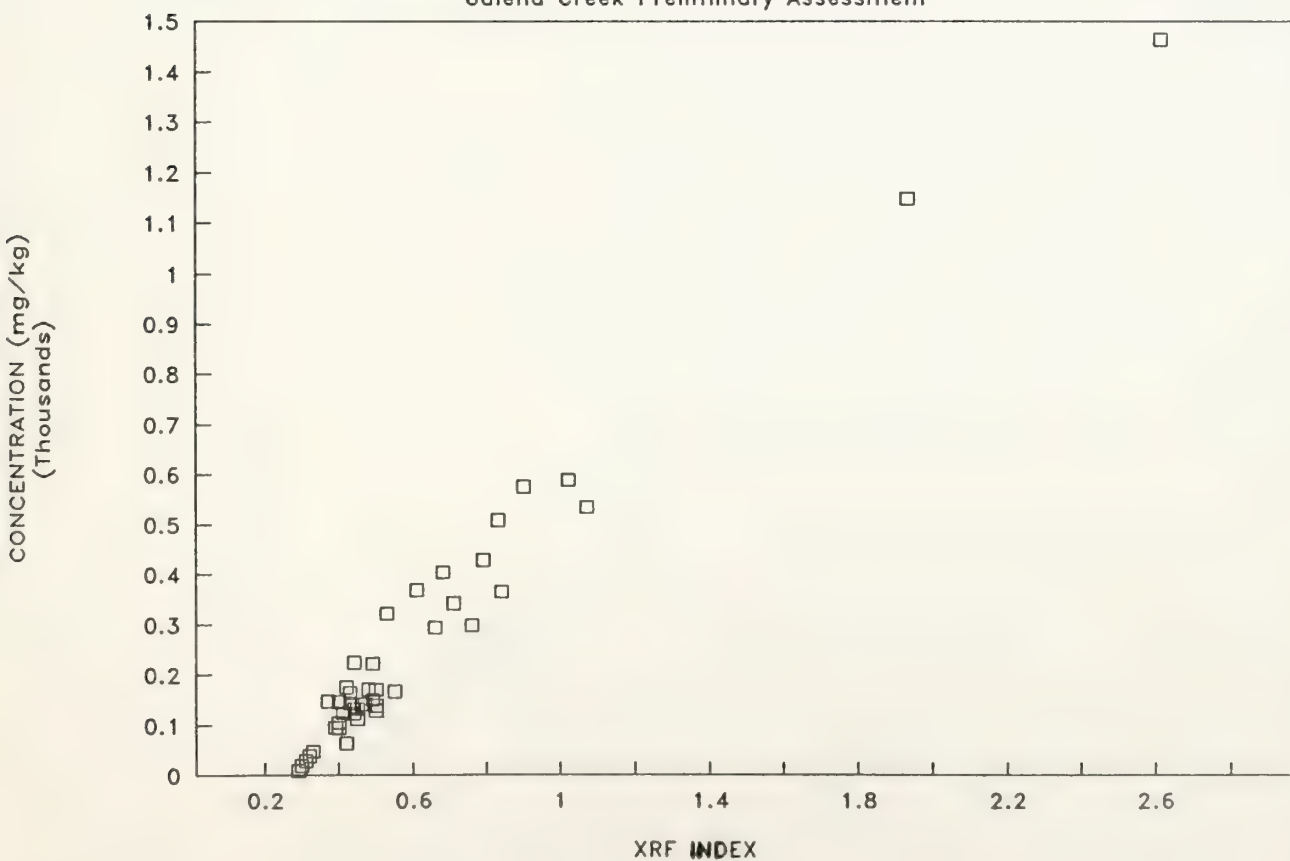
XRF ESTIMATED CONCENTRATION – ARSENIC

Galena Creek Preliminary Assessment



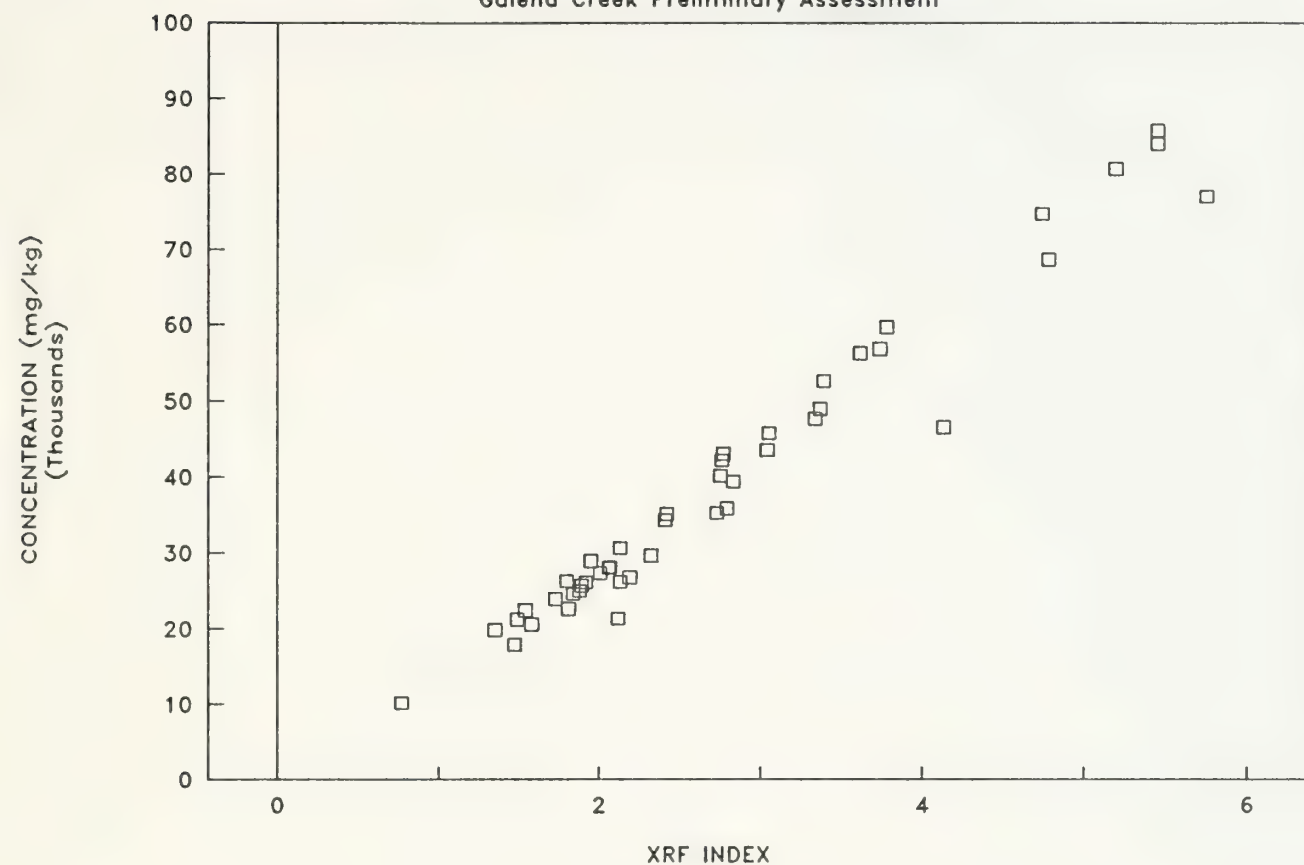
XRF ESTIMATED CONCENTRATION – COPPER

Galena Creek Preliminary Assessment



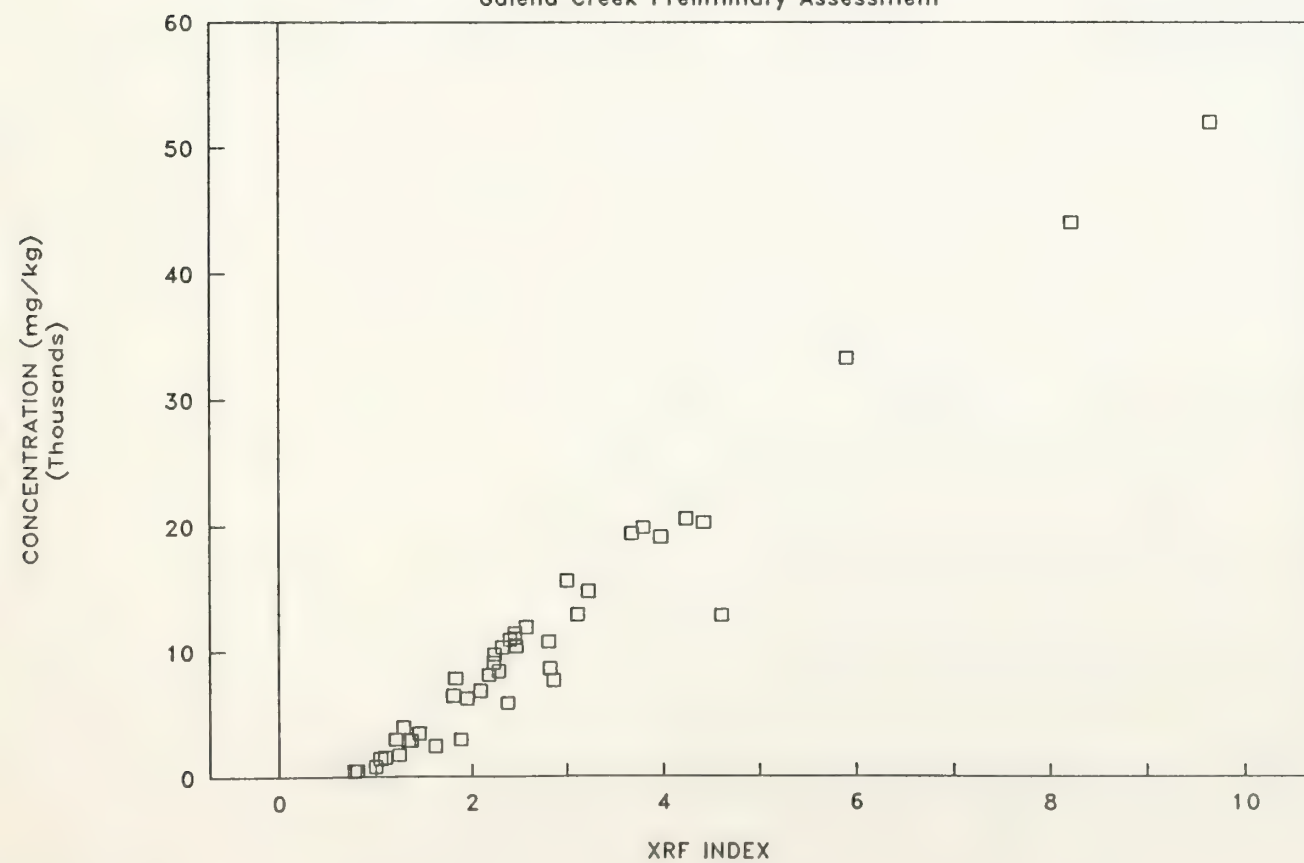
XRF ESTIMATED CONCENTRATION — IRON

Galena Creek Preliminary Assessment



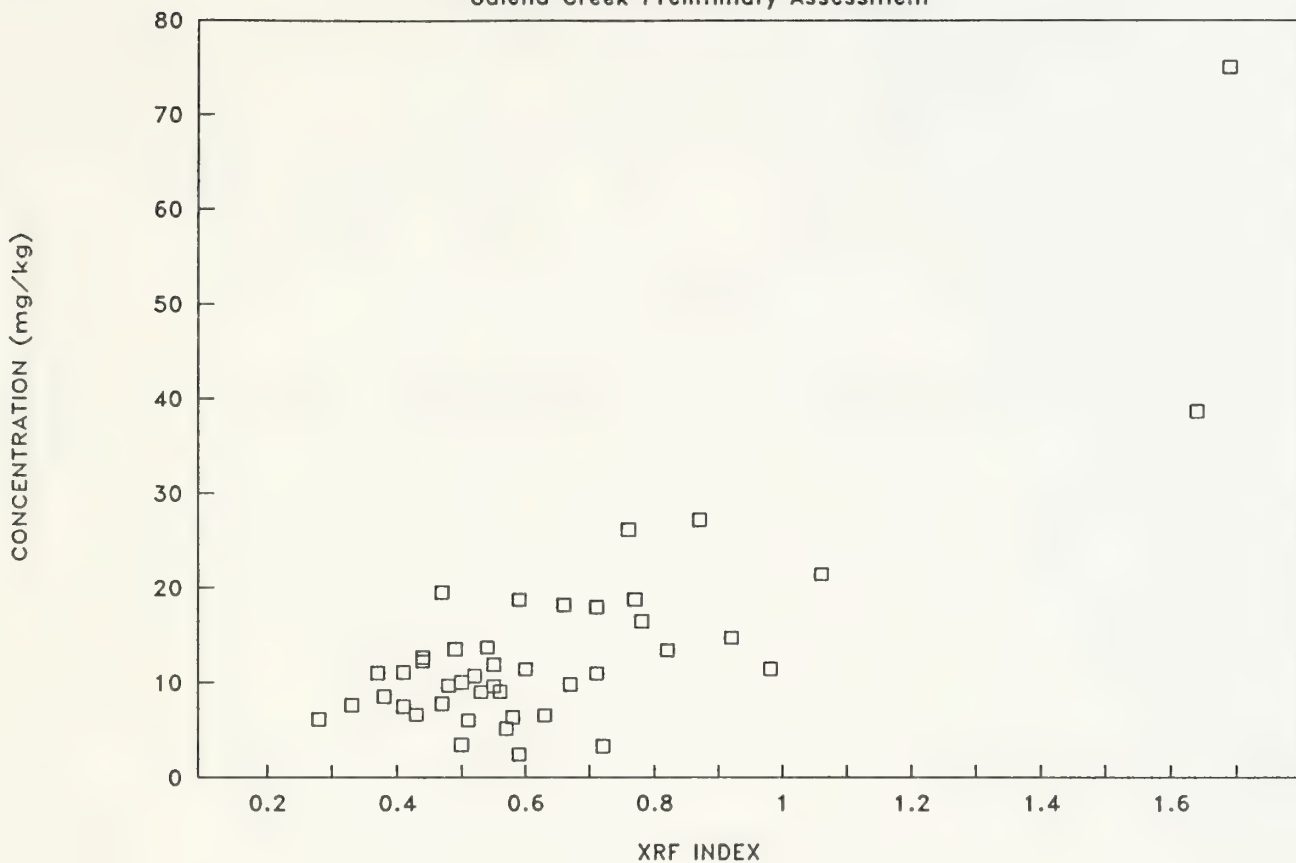
XRF ESTIMATED CONCENTRATION — LEAD

Galena Creek Preliminary Assessment



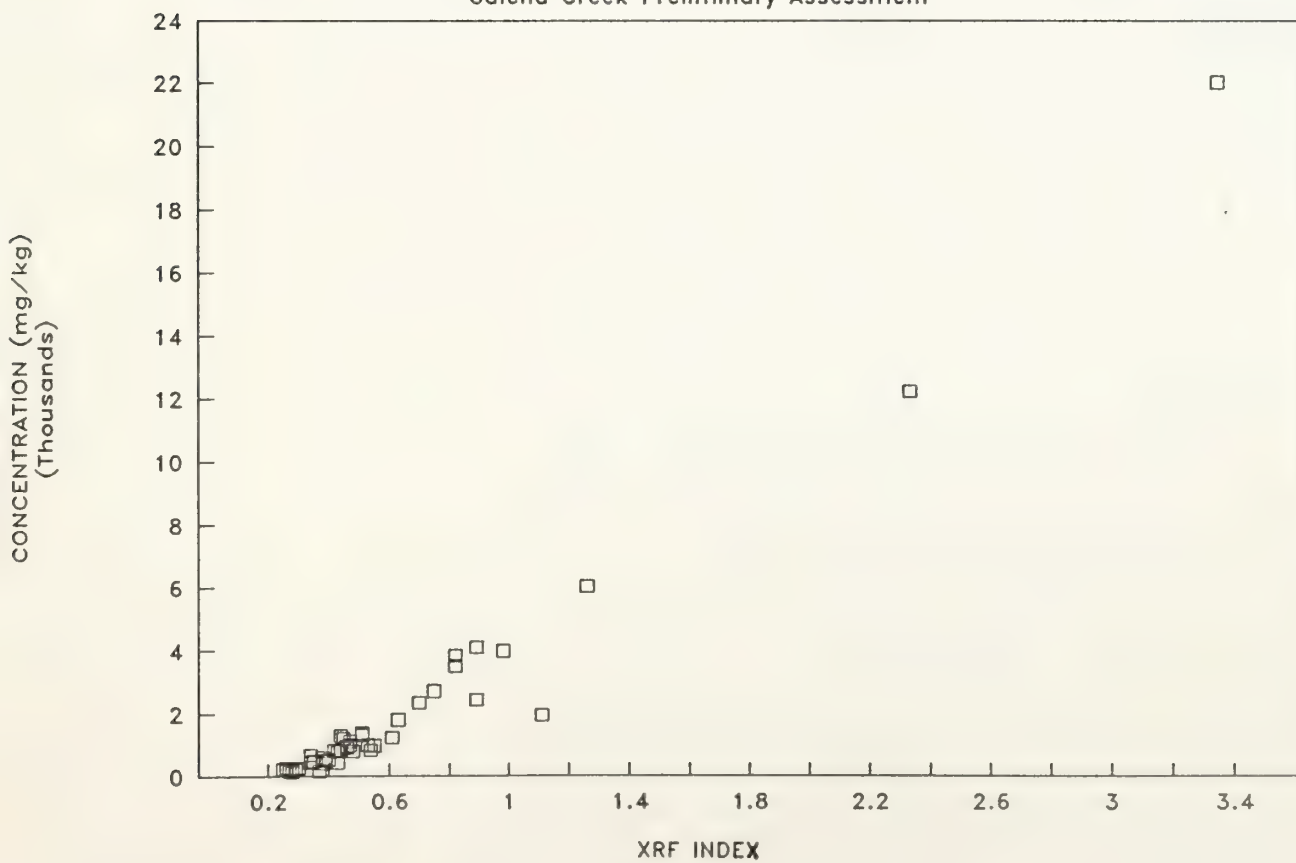
XRF ESTIMATED CONCENTRATION – NICKEL

Galena Creek Preliminary Assessment



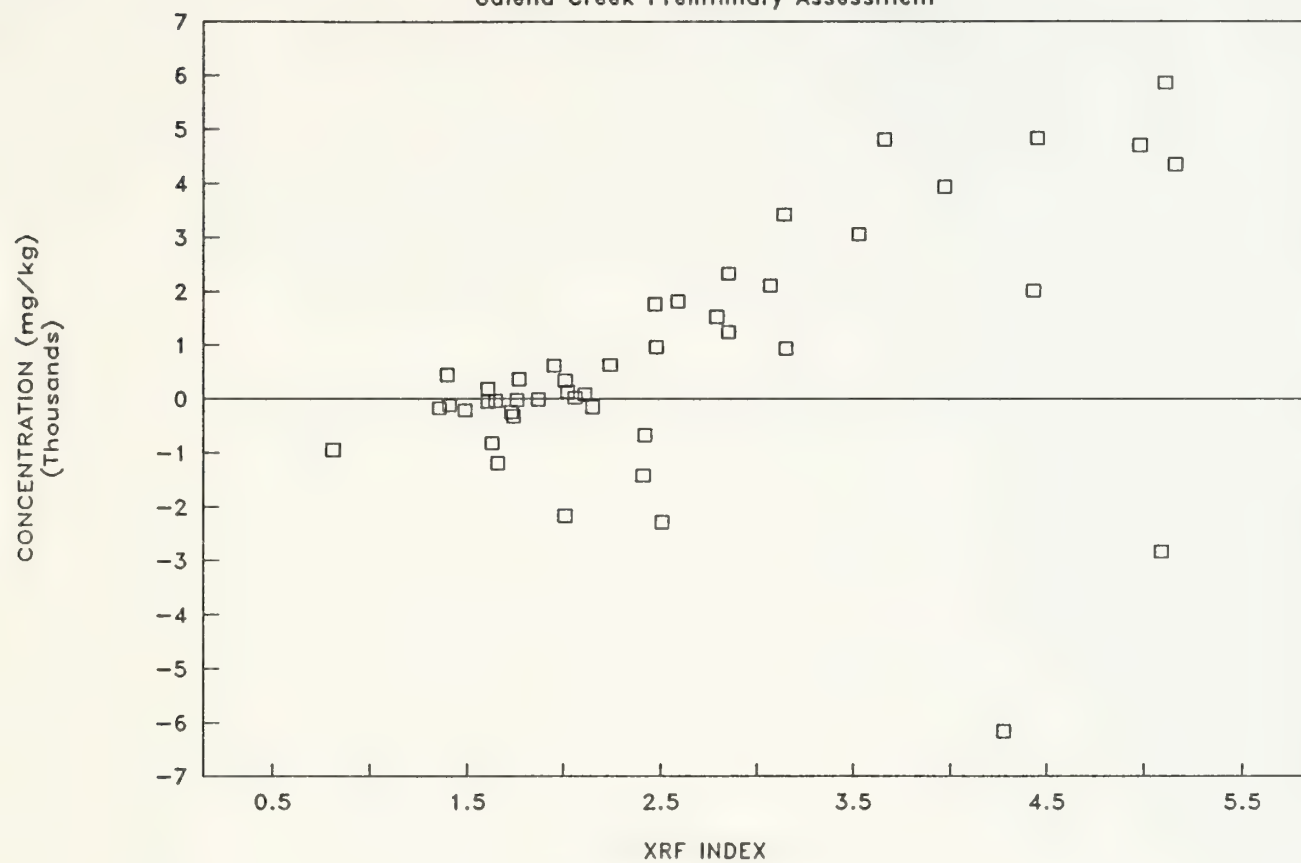
XRF ESTIMATED CONCENTRATION – ZINC

Galena Creek Preliminary Assessment



XRF ESTIMATED CONCENTRATION — MANGANESE

Galena Creek Preliminary Assessment



APPENDIX C-2

SOILS/MINE WASTE LABORATORY, GRADATION, AND HYDROMETER DATA BASE

HUGHESVILLE SOILS/MINE WASTE LABORATORY ANALYSES
Physical Properties

Station	Type	Sample Type	Sample Date	Lab Number	Top Interval (Inches)	Bottom Interval (Inches)	Field pH (s.u.)	Electrical Conductivity (Ds/cm/cm/mm)	Sample Texture	Percent Saturation
HW5	N	WASTE ROCK	11/07/90	109105	120	132	2.6	6.7		24.6
HW5	N	WASTE ROCK	11/07/90	109106	360	384	1.8	11.5		23.7
SS-100	N	STREAM TAILS	10/16/90	109061	0	1	2.7	0.8		21.4
SS-100	N	STREAM TAILS	10/16/90	109062	1	18	2.6	0.9		32.7
SS-100	N	SOIL	10/16/90	109063	18	26	3.2	0.6		30.1
SS-102	N	STREAM TAILS	10/16/90	109064	0	1	3.0	2.4	LOAMY SAND	23.3
SS-102	N	STREAM TAILS	10/16/90	109065	8	48	4.1	3.2	SAND	30.3
SS-102	N	STREAM TAILS	10/16/90	109066	48	60	4.0	0.5	LOAMY SAND	36.7
SS-105	N	STREAM TAILS	10/16/90	109067	0	1	2.9	0.5		21.1
SS-105	N	STREAM TAILS	10/16/90	109068	1	6	2.9	0.4		28.1
SS-105	N	SOIL	10/16/90	109069	6	12	3.8	3.4		37.4
SS-107	N	MILL TAILS	10/16/90	109051	66	72	1.6	14.4		38.1
SS-107	N	MILL TAILS	10/16/90	109070	0	1	1.6	37.3	SANDY LOAM	21.6
SS-107	LD	MILL TAILS	10/16/90	109070	0	1	1.6	38.1	SANDY LOAM	22.4
SS-107	N	MILL TAILS	10/16/90	109071	1	66	1.6	25.9	LOAMY SAND	23.5
SS-109	N	MILL TAILS	10/16/90	109052	0	1	1.4	45.7	SANDY LOAM	29.1
SS-109	N	MILL TAILS	10/16/90	109053	1	48	1.6	35.6	LOAMY SAND	24.9
SS-109	N	MILL TAILS	10/16/90	109054	48	66	1.8	20.7	LOAMY SAND	23.0
SS-109	N	MILL TAILS	10/16/90	109055	66	132	1.7	20.1	SANDY LOAM	23.9
SS-110	N	MILL TAILS	10/16/90	109056	0	1	1.6	29.6	LOAM	31.8
SS-110	N	MILL TAILS	10/16/90	109057	36	54	1.6	44.0	LOAMY SAND	24.0
SS-110	N	MILL TAILS	10/16/90	109058	84	90	4.0	27.0	SILT LOAM	35.8
SS-112	N	MILL TAILS	10/17/90	109039	156	178	1.5	29.4	SILT LOAM	75.2
SS-112	N	MILL TAILS	10/16/90	109059	0	1	1.6	30.0	CLAY LOAM	35.4
SS-112	N	SOIL	10/16/90	109060	216	222	1.8	20.1	SANDY LOAM	33.2
SS-112	LD	SOIL	10/16/90	109060	216	222	1.8	28.6		33.4
SS-115	N	WASTE ROCK	10/17/90	109032	0	1	2.2	3.2	LOAMY SAND	23.7
SS-115	N	WASTE ROCK	10/17/90	109033	12	36	2.1	4.7	SANDY LOAM	27.4
SS-117	N	WASTE ROCK	10/17/90	109034	0	1	2.2	1.5	SANDY LOAM	25.9
SS-117	N	WASTE ROCK	10/17/90	109035	18	36	2.4	3.4	SANDY LOAM	37.6
SS-117	N	WASTE ROCK	10/17/90	109036	36	48	2.2	4.0	SANDY LOAM	34.3
SS-121	N	WASTE ROCK	10/17/90	109037	18	36	2.1	4.8		33.4
SS-122	D	WASTE ROCK	10/17/90	109038	18	36	2.0	5.7		37.8
SS-124	N	WASTE ROCK	10/17/90	109040	0	1	2.1	2.7	SANDY LOAM	28.9
SS-124	LD	WASTE ROCK	10/17/90	109040	0	1	2.1	2.6		30.1

- 1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; LD - Laboratory Duplicate; N - Natural
2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range;
U - Less than detection limit; Z - Value not usable for statistics.
3) Blank values indicate parameters not determined.

HUGHESVILLE SOILS/MINE WASTE LABORATORY ANALYSES

Physical Properties

Station	Type	Sample Type	Sample Date	Lab Number	Top Interval (Inches)	Bottom Interval (Inches)	Field pH (s.u.)	Electrical Conductivity (DseImens/mm)	Sample Texture	Percent Saturation
SS-124	N	WASTE ROCK	10/17/90	109041	1	12	1.9	4.5	LOAMY SAND	24.0
SS-124	N	WASTE ROCK	10/17/90	109042	12	40	2.1	1.6	LOAMY SAND	27.6
SS-130	N	WASTE ROCK	10/18/90	109043	0	1	2.6	0.2	SANDY LOAM	30.0
SS-130	N	WASTE ROCK	10/18/90	109044	12	30	2.0	2.7	SANDY LOAM	35.1
SS-133	N	STREAM TAILS	10/18/90	109045	0	1	2.0	4.0	SANDY LOAM	25.0
SS-133	N	STREAM TAILS	10/18/90	109046	3	24	2.2	0.8	SANDY LOAM	34.9
SS-134	N	SOIL	10/18/90	109047	10	22	2.3	1.3	LOAMY SAND	24.4
SS-135	N	WASTE ROCK	10/18/90	109048	0	1	1.9	4.1	LOAMY SAND	25.5
SS-135	N	WASTE ROCK	10/18/90	109049	15	36	1.8	6.3	SANDY LOAM	27.4
SS-136	D	WASTE ROCK	10/18/90	109050	15	36	1.9	5.4		27.9
SS-136	LD	WASTE ROCK	10/18/90	109050	15	36	1.9	5.3		29.9
SS-137	N	WASTE ROCK	10/15/90	109102	0	1	5.3	4.7	SANDY LOAM	25.7
SS-137	N	WASTE ROCK	10/15/90	109103	1	24	4.6	11.0	SANDY LOAM	31.0
SS-137	N	WASTE ROCK	10/15/90	109104	24	48	1.6	1.7	SANDY LOAM	32.8
SS-150	BFS	STANDARD	11/19/90	109283	0					
SS-160	BFS	STANDARD	11/19/90	109284	0					

1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; LD - Laboratory Duplicate; N - Natural

2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; N - Laboratory spike recovery outside expected range; U - Less than detection limit; Z - Value not usable for statistics.

3) Blank values indicate parameters not determined.

HUGHESVILLE SOILS/MINE WASTE LABORATORY ANALYSES
Total and Saturated Paste Extract Metals Data

Station	Type	Sample Type	Sample Date	Top Interval (Inches)	Bottom Interval (Inches)	Aluminum Total (mg/kg)	Aluminum Extract (mg/l)	Arsenic Total (mg/kg)	Arsenic Extract (mg/l)	Cadmium Total (mg/kg)	Cadmium Extract (mg/l)
HW5	N	WASTE ROCK	11/07/90	120	132	4040		560		18.8	
HW5	N	WASTE ROCK	11/07/90	360	384	3410		340		9.7	
SS-100	N	STREAM TAILS	10/16/90	0	1	2410	2.0	920	0.072	23.0	0.655
SS-100	N	STREAM TAILS	10/16/90	1	18	5180	4.0	2040	0.040	17.0	0.474
SS-100	N	SOIL	10/16/90	18	26	13700		8		9.0	
SS-102	N	STREAM TAILS	10/16/90	0	1	2510	0.5	610	0.053	9.0	0.061
SS-102	N	STREAM TAILS	10/16/90	8	48	7390	1.5	160	0.005 U	14.0	1.200
SS-102	N	STREAM TAILS	10/16/90	48	60	9110		16		20.0	
SS-105	N	STREAM TAILS	10/16/90	0	1	1610	0.9	690	0.021	12.0	0.272
SS-105	N	STREAM TAILS	10/16/90	1	6	3290		1050		12.0	
SS-105	N	SOIL	10/16/90	6	12	6090		1910		25.0	
SS-107	LD	MILL TAILS	10/16/90	0	1	1620	1090.0	520	180.000	13.0	4.830
SS-107	N	MILL TAILS	10/16/90	66	72	6470		500		9.7	
SS-107	N	MILL TAILS	10/16/90	0	1	1610	1050.0	540	20.000	13.0	4.920
SS-107	N	MILL TAILS	10/16/90	1	66	1260	206.0	730	22.000	22.0	2.370
SS-109	N	MILL TAILS	10/16/90	0	1						
SS-109	N	MILL TAILS	10/16/90	1	48						
SS-109	N	MILL TAILS	10/16/90	48	66	1820	250.0	698	13.000	27.0	1.680
SS-109	N	MILL TAILS	10/16/90	66	132	2220	390.0	2140	370.000	68.0	3.710
SS-110	N	MILL TAILS	10/16/90	0	1						
SS-110	N	MILL TAILS	10/16/90	36	54						
SS-110	N	MILL TAILS	10/16/90	84	90						
SS-112	LD	SOIL	10/16/90	216	222	10800	1200.0	640	200.000	12.0	5.500
SS-112	N	MILL TAILS	10/17/90	156	178	5550	1400.0	1580	500.000	17.1	9.900
SS-112	N	MILL TAILS	10/16/90	0	1	5600	1870.0	920	380.000	15.0	9.100
SS-112	N	SOIL	10/16/90	216	222	10700	1380.0	660	200.000	12.0	5.800
SS-115	N	WASTE ROCK	10/17/90	0	1	2290		720		7.4	
SS-115	N	WASTE ROCK	10/17/90	12	36	2400		324		5.9	
SS-117	N	WASTE ROCK	10/17/90	0	1	1910	11.0	299	0.021	8.1	0.075
SS-117	N	WASTE ROCK	10/17/90	18	36	2620	59.0	312	0.040	8.3	0.388
SS-117	N	WASTE ROCK	10/17/90	36	48	2360	29.0	312	0.076	11.3	0.346
SS-121	N	WASTE ROCK	10/17/90	18	36	3910	74.0	457	0.110	8.4	0.339
SS-122	D	WASTE ROCK	10/17/90	18	36	4370	78.0	1030	0.400	9.9	0.236
SS-124	LD	WASTE ROCK	10/17/90	0	1	2980	58.0	388	0.140	17.0	0.255

1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; LD - Laboratory Duplicate; N - Natural

2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range; U - Less than detection limit; Z - Value not usable for statistics.

3) Blank values indicate parameters not determined.

HUGHESVILLE SOILS/MINE WASTE LABORATORY ANALYSES
Total and Saturated Paste Extract Metals Data

Station	Type	Sample Type	Sample Date	Top Interval (Inches)	Bottom Interval (Inches)	Aluminum Total (mg/kg)	Aluminum Extract (mg/l)	Arsenic Total (mg/kg)	Arsenic Extract (mg/l)	Cadmium Total (mg/kg)	Cadmium Extract (mg/l)
SS-124	N	WASTE ROCK	10/17/90	0	1	3220	58.0	365	0.180	17.2	0.330
SS-124	N	WASTE ROCK	10/17/90	1	12	1750	37.0	311	0.425	7.6	0.250
SS-124	N	WASTE ROCK	10/17/90	12	40	2410	2.1	380	0.023	4.4	0.024
SS-130	N	WASTE ROCK	10/18/90	0	1	2390	0.4	510	0.010	14.0	0.013
SS-130	N	WASTE ROCK	10/18/90	12	30	2360		840		16.0	
SS-133	N	STREAM TAILS	10/18/90	0	1	1830	15.0	2010	0.092	44.0	1.520
SS-133	N	STREAM TAILS	10/18/90	3	24	2350		1600		11.0	
SS-134	N	SOIL	10/18/90	10	22	5410		897		10.0	
SS-135	N	WASTE ROCK	10/18/90	0	1	2000	11.0	220	0.154	9.2	0.200
SS-135	N	WASTE ROCK	10/18/90	15	36	2090	30.0	116	0.407	10.0	0.698
SS-136	D	WASTE ROCK	10/18/90	15	36	3150	16.0	160	0.341	12.0	0.606
SS-136	LD	WASTE ROCK	10/18/90	15	36	3190	16.0	164	0.253	14.0	0.596
SS-137	N	WASTE ROCK	10/15/90	0	1	4400		270		37.0	
SS-137	N	WASTE ROCK	10/15/90	1	24	3920		490		28.0	
SS-137	N	WASTE ROCK	10/15/90	24	48	1810		670		25.0	
SS-150	BFS	STANDARD	11/19/90	0		13600		70		42.7	
SS-160	BFS	STANDARD	11/19/90	0		13300		73		42.7	

1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; LD - Laboratory Duplicate; N - Natural

2) Data-quality analysis codes are defined as: A - Blind field standard outside advisory range; N - Laboratory spike recovery outside control limits; R - Field duplicates outside expected range;
U - Less than detection limit; Z - Value not usable for statistics.

3) Blank values indicate parameters not determined.

HUGHESVILLE SOILS/MINE WASTE LABORATORY ANALYSES
Total and Saturated Paste Extract Metals Data

Station	Type	Sample Type	Sample Date	Top Interval (Inches)	Bottom Interval (Inches)	Chromium Total (mg/kg)	Chromium Extract (mg/l)	Copper Total (mg/kg)	Copper Extract (mg/l)	Iron Total (mg/kg)	Iron Extract (mg/l)
HW5	N	WASTE ROCK	11/07/90	120	132	7		106		37800	
HW5	N	WASTE ROCK	11/07/90	360	384	7		55		39700	
SS-100	N	STREAM TAILS	10/16/90	0	1	2	0.02 U	220	0.54	23200	7.20
SS-100	N	STREAM TAILS	10/16/90	1	18	10	0.02	130	1.00	60000	9.60
SS-100	N	SOIL	10/16/90	18	26	47		187		23500	
SS-102	N	STREAM TAILS	10/16/90	0	1	2	0.02 U	138	0.29	22900	0.57
SS-102	N	STREAM TAILS	10/16/90	8	48	14	0.12	268	1.20	37300	0.19
SS-102	N	STREAM TAILS	10/16/90	48	60	20		369		12300	
SS-105	N	STREAM TAILS	10/16/90	0	1	2	0.04	349	0.32	26100	1.30
SS-105	N	STREAM TAILS	10/16/90	1	6	2	U	410		34400	
SS-105	N	SOIL	10/16/90	6	12	12		580		73600	
SS-107	LD	MILL TAILS	10/16/90	0	1	2	0.20 U	254	43.00	43400	31100.00
SS-107	N	MILL TAILS	10/16/90	66	72	7		79		27300	
SS-107	N	MILL TAILS	10/16/90	0	1	2	0.20 U	254	44.00	44200	30700.00
SS-107	N	MILL TAILS	10/16/90	1	66	2	U	179	18.00	78400	9850.00
SS-109	N	MILL TAILS	10/16/90	0	1						
SS-109	N	MILL TAILS	10/16/90	1	48						
SS-109	N	MILL TAILS	10/16/90	48	66	2	0.66	157	23.00	91500	4900.00
SS-109	N	MILL TAILS	10/16/90	66	132	2	3.53	688	290.00	141000	8100.00
SS-110	N	MILL TAILS	10/16/90	0	1						
SS-110	N	MILL TAILS	10/16/90	36	54						
SS-110	N	MILL TAILS	10/16/90	84	90						
SS-112	LD	SOIL	10/16/90	216	222	14	3.15	190	130.00	33900	14700.00
SS-112	N	MILL TAILS	10/17/90	156	178	10	4.10	314	305.00	81000	48200.00
SS-112	N	MILL TAILS	10/16/90	0	1	4	2.06	312	116.00	50400	43800.00
SS-112	N	SOIL	10/16/90	216	222	14	3.28	190	150.00	32800	16400.00 U
SS-115	N	WASTE ROCK	10/17/90	0	1	3		46		30700	
SS-115	N	WASTE ROCK	10/17/90	12	36	2		76		27500	
SS-117	N	WASTE ROCK	10/17/90	0	1	2	0.08	88	0.66	29100	8.00
SS-117	N	WASTE ROCK	10/17/90	18	36	4	0.09	93	2.12	29300	9.70
SS-117	N	WASTE ROCK	10/17/90	36	48	3	0.04	111	1.01	39600	47.00
SS-121	N	WASTE ROCK	10/17/90	18	36	6	0.12	32	1.60	41100	82.00
SS-122	D	WASTE ROCK	10/17/90	18	36	7	0.05	37	2.10	54900	230.00
SS-124	LD	WASTE ROCK	10/17/90	0	1	3	0.10	55	0.55	25900	43.00

1) Sample Types are defined as: BFS - Blind Field Standard; D - Field Duplicate; LD - Laboratory Duplicate; N - Natural

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U - Less than detection limit; Z - Value not usable for statistics.

3) Blank values indicate parameters not determined.

HUGHESVILLE SOILS/MINE WASTE LABORATORY ANALYSES
Total and Saturated Paste Extract Metals Data

Station	Type	Sample Type	Sample Date	Top Interval (Inches)	Bottom Interval (Inches)	Chromium Total (mg/kg)	Chromium Extract (mg/l)	Copper Total (mg/kg)	Copper Extract (mg/l)	Iron Total (mg/kg)	Iron Extract (mg/l)
SS-124	N	WASTE ROCK	10/17/90	0	1	4	0.15	57	0.80	27300	45.00
SS-124	N	WASTE ROCK	10/17/90	1	12	2	0.10	31	0.85	16600	181.00
SS-124	N	WASTE ROCK	10/17/90	12	40	2	0.02	11	0.19	15700	5.80
SS-130	N	WASTE ROCK	10/18/90	0	1	2	0.02	332	0.12	33300	0.41
SS-130	N	WASTE ROCK	10/18/90	12	30	2	U	172		40100	
SS-133	N	STREAM TAILS	10/18/90	0	1	34	0.04	568	3.65	65400	120.00
SS-133	N	STREAM TAILS	10/18/90	3	24	4		206		25200	
SS-134	N	SOIL	10/18/90	10	22	10		36		37000	
SS-135	N	WASTE ROCK	10/18/90	0	1	2	0.04	40	0.71	17400	220.00
SS-135	N	WASTE ROCK	10/18/90	15	36	2	0.05	129	2.22	15400	490.00
SS-136	D	WASTE ROCK	10/18/90	15	36	2	0.04	158	1.49	17900	350.00
SS-136	LD	WASTE ROCK	10/18/90	15	36	2	U	160	1.59	18500	360.00
SS-137	N	WASTE ROCK	10/15/90	0	1	28		2140		134000	
SS-137	N	WASTE ROCK	10/15/90	1	24	28		483		121000	
SS-137	N	WASTE ROCK	10/15/90	24	48	7		845		148000	
SS-150	BFS	STANDARD	11/19/90	0		50		160		19500	
SS-160	BFS	STANDARD	11/19/90	0		51		190		19800	

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U - Less than detection limit; Z - Value not usable for statistics.

3) Blank values indicate parameters not determined.

HUGHESVILLE SOILS/MINE WASTE LABORATORY ANALYSES
Total and Saturated Paste Extract Metals Data

Station	Type	Sample Type	Sample Date	Top Interval (Inches)	Bottom Interval (Inches)	Lead Total (mg/kg)	Lead Extract (mg/l)	Manganese Total (mg/kg)	Manganese Extract (mg/l)	Mercury Total (mg/kg)	Mercury Extract (mg/l)
HW5	N	WASTE ROCK	11/07/90	120	132	11500		216		0.64	
HW5	N	WASTE ROCK	11/07/90	360	384	1490		49		0.26	
SS-100	N	STREAM TAILS	10/16/90	0	1	13500	2.57	28	3.00	0.72	0.002 U
SS-100	N	STREAM TAILS	10/16/90	1	18	6340	0.16	180	2.20	0.36	0.045
SS-100	N	SOIL	10/16/90	18	26	91		123		0.07	
SS-102	N	STREAM TAILS	10/16/90	0	1	6130	0.13	38	0.35	0.27	0.013
SS-102	N	STREAM TAILS	10/16/90	8	48	451	0.29	1340	58.00	0.05	0.003
SS-102	N	STREAM TAILS	10/16/90	48	60	408		94		0.08	
SS-105	N	STREAM TAILS	10/16/90	0	1	12200	5.90	26	1.79	0.62	0.002 U
SS-105	N	STREAM TAILS	10/16/90	1	6	18500		76		0.85	
SS-105	N	SOIL	10/16/90	6	12	1540		10900		0.24	
SS-107	LD	MILL TAILS	10/16/90	0	1	4000	2.46	18	3.47	0.36	0.002 U
SS-107	N	MILL TAILS	10/16/90	66	72	2810		10		0.20	
SS-107	N	MILL TAILS	10/16/90	0	1	4340	2.41	26	3.11	0.35	0.002 U
SS-107	N	MILL TAILS	10/16/90	1	66	2310	3.66	6	1.90	0.45	0.004
SS-109	N	MILL TAILS	10/16/90	0	1						
SS-109	N	MILL TAILS	10/16/90	1	48						
SS-109	N	MILL TAILS	10/16/90	48	66	2070	2.92	67	280.00	0.44	0.002 U
SS-109	N	MILL TAILS	10/16/90	66	132	4460	8.00	115	420.00	0.94	0.002 U
SS-110	N	MILL TAILS	10/16/90	0	1						
SS-110	N	MILL TAILS	10/16/90	36	54						
SS-110	N	MILL TAILS	10/16/90	84	90						
SS-112	LD	SOIL	10/16/90	216	222	680	0.53	1440	4850.00	0.10	0.020 U
SS-112	N	MILL TAILS	10/17/90	156	178	10000	2.40	3290	8700.00	1.00	1.250
SS-112	N	MILL TAILS	10/16/90	0	1	10600	0.47	1630	6100.00	0.42	0.002 U
SS-112	N	SOIL	10/16/90	216	222	720	0.20	1400	5100.00	0.10	0.020 U
SS-115	N	WASTE ROCK	10/17/90	0	1	11100		38		0.20	
SS-115	N	WASTE ROCK	10/17/90	12	36	4050		45		0.44	
SS-117	N	WASTE ROCK	10/17/90	0	1	10200	4.32	16	2.08	0.66	0.004
SS-117	N	WASTE ROCK	10/17/90	18	36	23600	2.13	34	3.58	1.40	0.002 U
SS-117	N	WASTE ROCK	10/17/90	36	48	24600	2.26	31	3.73	1.30	0.002 U
SS-121	N	WASTE ROCK	10/17/90	18	36	4210	2.07	26	2.64	0.59	0.002
SS-122	D	WASTE ROCK	10/17/90	18	36	9360	1.43	29	3.13	0.73	5.020
SS-124	LD	WASTE ROCK	10/17/90	0	1	40700	3.50	36	15.00	0.52	0.002 U

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U - Less than detection limit; Z - Value not usable for statistics.

3) Blank values indicate parameters not determined.

HUGHESVILLE SOILS/MINE WASTE LABORATORY ANALYSES
Total and Saturated Paste Extract Metals Data

Station	Type	Sample Type	Sample Date	Top Interval (Inches)	Bottom Interval (Inches)	Lead Total (mg/kg)	Lead Extract (mg/l)	Manganese Total (mg/kg)	Manganese Extract (mg/l)	Mercury Total (mg/kg)	Mercury Extract (mg/l)
SS-124	N	WASTE ROCK	10/17/90	0	1	34600	3.40	39	17.00	0.52	0.002 U
SS-124	N	WASTE ROCK	10/17/90	1	12	3270	2.70	9	5.05	0.20	0.002 U
SS-124	N	WASTE ROCK	10/17/90	12	40	291	0.17	8	0.68	0.44	0.002 U
SS-130	N	WASTE ROCK	10/18/90	0	1	34000	5.50	29	0.12	2.80	0.011
SS-130	N	WASTE ROCK	10/18/90	12	30	9170		38		1.80	
SS-133	N	STREAM TAILS	10/18/90	0	1	18600	1.17	63	1.90	2.10	0.004 U
SS-133	N	STREAM TAILS	10/18/90	3	24	18000		40		1.30	
SS-134	N	SOIL	10/18/90	10	22	1030		1410		0.07	
SS-135	N	WASTE ROCK	10/18/90	0	1	22000	3.03	13	1.46	0.51	0.002 U
SS-135	N	WASTE ROCK	10/18/90	15	36	12200	2.55	31	17.00	1.60	0.002 U
SS-136	D	WASTE ROCK	10/18/90	15	36	22800	2.55	28	7.30	1.90	0.003
SS-136	LD	WASTE ROCK	10/18/90	15	36	22800	2.81	29	7.40	1.80	0.002
SS-137	N	WASTE ROCK	10/15/90	0	1	8690		15600		0.07	
SS-137	N	WASTE ROCK	10/15/90	1	24	1740		5100		0.27	
SS-137	N	WASTE ROCK	10/15/90	24	48	4100		2040		0.32	
SS-150	BFS	STANDARD	11/19/90	0		32		350		1.20	
SS-160	BFS	STANDARD	11/19/90	0		30		350		1.40	

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U - Less than detection limit; Z - Value not usable for statistics.

3) Blank values indicate parameters not determined.

HUGHESVILLE SOILS/MINE WASTE LABORATORY ANALYSES
Total and Saturated Paste Extract Metals Data

Station	Type	Sample Type	Sample Date	Top Interval (Inches)	Bottom Interval (Inches)	Nickel Total (mg/kg)	Nickel Extract (mg/l)	Silver Total (mg/kg)	Silver Extract (mg/l)	Zinc Total (mg/kg)	Zinc Extract (mg/l)
HW5	N	WASTE ROCK	11/07/90	120	132	8.9		64		2800	
HW5	N	WASTE ROCK	11/07/90	360	384	9.0		8		204	
SS-100	N	STREAM TAILS	10/16/90	0	1	13.0	0.02	150	0.02	3010	96.00
SS-100	N	STREAM TAILS	10/16/90	1	18	28.0	0.02	80	0.02	630	64.00
SS-100	N	SOIL	10/16/90	18	26	37.0		2		478	
SS-102	N	STREAM TAILS	10/16/90	0	1	10.0	0.02	43	0.02	553	8.80
SS-102	N	STREAM TAILS	10/16/90	8	48	24.0	0.19	4	0.03	1220	401.00
SS-102	N	STREAM TAILS	10/16/90	48	60	22.0		2		858	
SS-105	N	STREAM TAILS	10/16/90	0	1	11.0	0.02	229	0.02	1450	38.00
SS-105	N	STREAM TAILS	10/16/90	1	6	12.0		156		1090	
SS-105	N	SOIL	10/16/90	6	12	27.0		18		1070	
SS-107	LD	MILL TAILS	10/16/90	0	1	16.0	4.17	108	0.25	588	130.00
SS-107	N	MILL TAILS	10/16/90	66	72	12.0		19		562	
SS-107	N	MILL TAILS	10/16/90	0	1	14.0	3.98	109	0.24	636	130.00
SS-107	N	MILL TAILS	10/16/90	1	66	22.0	1.45	113	0.26	950	140.00
SS-109	N	MILL TAILS	10/16/90	0	1						
SS-109	N	MILL TAILS	10/16/90	1	48						
SS-109	N	MILL TAILS	10/16/90	48	66	22.0	1.34	68	0.14	905	100.00
SS-109	N	MILL TAILS	10/16/90	66	132	38.0	2.23	113	0.30	76	390.00
SS-110	N	MILL TAILS	10/16/90	0	1						
SS-110	N	MILL TAILS	10/16/90	36	54						
SS-110	N	MILL TAILS	10/16/90	84	90						
SS-112	LD	SOIL	10/16/90	216	222	21.0	3.73	6	0.84	321	550.00
SS-112	N	MILL TAILS	10/17/90	156	178	13.0	5.02	54	1.25	860	930.00
SS-112	N	MILL TAILS	10/16/90	0	1	14.0	5.71	72	0.84	731	1050.00
SS-112	N	SOIL	10/16/90	216	222	18.0	3.83	6	0.89	321	660.00
SS-115	N	WASTE ROCK	10/17/90	0	1	5.0		25		314	2.20
SS-115	N	WASTE ROCK	10/17/90	12	36	6.0		18		130	
SS-117	N	WASTE ROCK	10/17/90	0	1	3.0	0.06	38	0.02	453	11.00
SS-117	N	WASTE ROCK	10/17/90	18	36	7.0	0.02	56	0.02	340	54.00
SS-117	N	WASTE ROCK	10/17/90	36	48	9.7	0.07	74	0.02	975	66.00
SS-121	N	WASTE ROCK	10/17/90	18	36	4.0	0.08	26	0.11	313	34.00
SS-122	D	WASTE ROCK	10/17/90	18	36	8.0	0.02	21	0.02	184	38.00
SS-124	LD	WASTE ROCK	10/17/90	0	1	5.0	0.25	107	0.10	2150	42.00

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3) Blank values indicate parameters not determined.

HUGHESVILLE SOILS/MINE WASTE LABORATORY ANALYSES
Total and Saturated Paste Extract Metals Data

Station	Type	Sample Type	Sample Date	Top Interval (Inches)	Bottom Interval (Inches)	Nickel Total (mg/kg)	Nickel Extract (mg/l)	Silver Total (mg/kg)	Silver Extract (mg/l)	Zinc Total (mg/kg)	Zinc Extract (mg/l)
SS-124	N	WASTE ROCK	10/17/90	0	1	5.0	0.15	104	0.10	2010	42.00
SS-124	N	WASTE ROCK	10/17/90	1	12	6.0	0.10	39	0.10	262	35.00
SS-124	N	WASTE ROCK	10/17/90	12	40	8.0	0.02	4	0.02	78	3.88
SS-130	N	WASTE ROCK	10/18/90	0	1	8.0	0.04	176	0.02	792	2.16
SS-130	N	WASTE ROCK	10/18/90	12	30	10.0		96		626	
SS-133	N	STREAM TAILS	10/18/90	0	1	17.0	0.15	440	0.02	4830	245.00
SS-133	N	STREAM TAILS	10/18/90	3	24	10.0		170		558	
SS-134	N	SOIL	10/18/90	10	22	16.0		4		249	
SS-135	N	WASTE ROCK	10/18/90	0	1	13.0	0.13	43	0.02	388	24.00
SS-135	N	WASTE ROCK	10/18/90	15	36	8.0	0.21	56	0.02	1000	98.00
SS-136	D	WASTE ROCK	10/18/90	15	36	10.0	0.15	115	0.02	1680	80.00
SS-136	LD	WASTE ROCK	10/18/90	15	36	10.0	0.16	106		2000	82.00
SS-137	N	WASTE ROCK	10/15/90	0	1	42.0		132	0.02	1580	
SS-137	N	WASTE ROCK	10/15/90	1	24	30.0		33		613	
SS-137	N	WASTE ROCK	10/15/90	24	48	22.0		52		503	
SS-150	BFS	STANDARD	11/19/90	0		120.0		76		350	
SS-160	BFS	STANDARD	11/19/90	0		130.0		83		360	

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HUGHESVILLE SOILS/MINE WASTE LABORATORY ANALYSIS
Sulfur Fractionation

Station	Type	Sample Type	Sample Date	Top Interval	Bottom Interval	Total Sulfur (%)	Sulfate Sulfur (%)	Jarosite Sulfur (%)	Pyritic Sulfur (%)	Residual Sulfur (%)
HW5	N	WASTE ROCK	11/07/90	120	132					
HW5	N	WASTE ROCK	11/07/90	360	384					
SS-100	N	STREAM TAILS	10/16/90	0	1					
SS-100	N	STREAM TAILS	10/16/90	1	18					
SS-100	N	SOIL	10/16/90	18	26					
SS-102	N	STREAM TAILS	10/16/90	0	1					
SS-102	N	STREAM TAILS	10/16/90	8	48	0.37	0.10	0.02	0.20	0.01
SS-102	N	STREAM TAILS	10/16/90	48	60	0.13	0.01	0.07	0.06	0.01
SS-105	N	STREAM TAILS	10/16/90	0	1					
SS-105	N	STREAM TAILS	10/16/90	1	6					
SS-105	N	SOIL	10/16/90	6	12					
SS-107	LD	MILL TAILS	10/16/90	0	1	3.83	0.71	0.45	1.21	1.46
SS-107	N	MILL TAILS	10/16/90	66	72					
SS-107	N	MILL TAILS	10/16/90	0	1	3.82	0.73	0.45	1.39	1.25
SS-107	N	MILL TAILS	10/16/90	1	66	8.96	0.38	0.29	5.65	2.64
SS-109	N	MILL TAILS	10/16/90	0	1					
SS-109	N	MILL TAILS	10/16/90	1	48					
SS-109	N	MILL TAILS	10/16/90	48	66					
SS-109	N	MILL TAILS	10/16/90	66	132					
SS-110	N	MILL TAILS	10/16/90	0	1					
SS-110	N	MILL TAILS	10/16/90	36	54	9.53	0.13	0.48	7.58	1.34
SS-110	N	MILL TAILS	10/16/90	84	90	9.45	0.32	0.91	6.30	1.92
SS-112	LD	SOIL	10/16/90	216	222					
SS-112	N	MILL TAILS	10/17/90	156	178	6.22	1.20	1.74	2.30	0.98
SS-112	N	MILL TAILS	10/16/90	0	1					
SS-112	N	SOIL	10/16/90	216	222					
SS-115	N	WASTE ROCK	10/17/90	0	1					
SS-115	N	WASTE ROCK	10/17/90	12	36	0.97	0.68	0.09	0.11	0.09
SS-117	N	WASTE ROCK	10/17/90	0	1					
SS-117	N	WASTE ROCK	10/17/90	18	36	1.32	0.87	0.10	0.10	0.34
SS-117	N	WASTE ROCK	10/17/90	36	48	2.29	1.22	0.43	0.30	0.34
SS-121	N	WASTE ROCK	10/17/90	18	36					
SS-122	D	WASTE ROCK	10/17/90	18	36					
SS-124	LD	WASTE ROCK	10/17/90	0	1					

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3) Blank values indicate parameters not determined.

HUGHESVILLE SOILS/MINE WASTE LABORATORY ANALYSIS
Sulfur Fractionation

Station	Type	Sample Type	Sample Date	Top Interval	Bottom Interval	Total Sulfur (%)	Sulfate Sulfur (%)	Jarosite Sulfur (%)	Pyritic Sulfur (%)	Residual Sulfur (%)
SS-124	N	WASTE ROCK	10/17/90	0	1					
SS-124	N	WASTE ROCK	10/17/90	1	12					
SS-124	N	WASTE ROCK	10/17/90	12	40					
SS-130	N	WASTE ROCK	10/18/90	0	1					
SS-130	N	WASTE ROCK	10/18/90	12	30	1.58	1.07	0.04	0.39	0.08
SS-133	N	STREAM TAILS	10/18/90	0	1					
SS-133	N	STREAM TAILS	10/18/90	3	24					
SS-134	N	SOIL	10/18/90	10	22					
SS-135	N	WASTE ROCK	10/18/90	0	1					
SS-135	N	WASTE ROCK	10/18/90	15	36					
SS-135	N	WASTE ROCK	10/18/90	15	36					
SS-136	LD	WASTE ROCK	10/18/90	15	36					
SS-136	N	WASTE ROCK	10/15/90	0	1					
SS-137	N	WASTE ROCK	10/15/90	1	24	5.81	1.41	1.41	1.44	1.55
SS-137	N	WASTE ROCK	10/15/90	24	48	5.21	1.59	1.88	0.91	0.83
SS-150	BFS	STANDARD	11/19/90	0						
SS-160	BFS	STANDARD	11/19/90	0						

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